GAS ENGINES: Their Advantages, Action, and Application.

Hints to Purchasers, Erectors, and Attendants.

By W. A. TOOKEY.

Parts—I. Deals with the Advantages over Steam, Costs as regards Up-keep, Attendance, Erection, Powers, Designs, Hints to Buyers, and Explains How Gas Engines Work. II. Deals with Gas, Air, Exhaust, and Water Connections, Foundations and Suitable Sites, and Hints to Erectors. III. Deals with Starting and Starters, Failures and Defects, and Hints to Attendants. Price **1s.** net; post free **1s. 2d.**

OIL ENGINES: Their Selection, Erection, and Correction.

Hints to Purchasers, Erectors, and Attendants.

By W. A. TOOKEY.

Parts—I. Deals with Petroleum, Advantages and Powers of Oil Engines, and Explains How Oil Engines Work. II. Deals with the Selection of Engine, and Describes Various Designs of Parts, with Hints to Purchasers. III. Deals with Erection and Connections of Oil, Air, Exhaust, etc., also with Foundations and Suitable Sites, with Hints to Erectors. IV. Deals with Starting and Starters, Running, Failures and Defects, with Hints to Attendants; Appendix. Nineteen Oil Engines of Different Makes are Illustrated and Briefly Described, thus enabling a Prospective Purchaser to Compare Designs. Price **1s.** net; post free **1s. 2d.**

GAS PRODUCERS for Power Purposes.

A Handbook for the Use of Purchasers, Erectors, and Attendants.

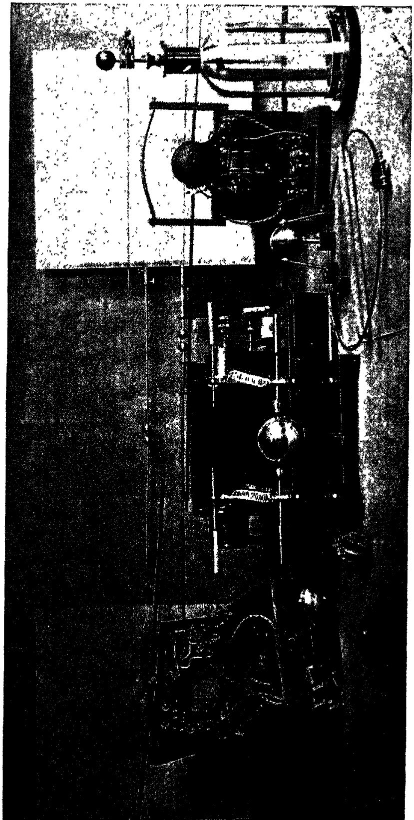
By W. A. TOOKEY.

Introduction—Describes briefly the Processes of Manufacture of Coal, Water, Oil, and Acetylene Gases. Parts—I. Deals with the Method of Generation of Producer Gas, its Composition and Qualities and Cost. II. Deals with the Generation of Gas from Different Materials by Different Processes, with Descriptions and Illustrations of Various Plants. III. Hints to Erectors and Attendants and General Remarks. IV. Appendix. Sixteen Different Kinds of Plants are Described, and many are Illustrated with Sectional Drawings, Showing Methods of Working. Price **1s.** net; post free **1s. 2½d.**

From all Booksellers, or Post free for **1s. 2d.** *each from*

PERCIVAL MARSHALL & Co., 26-29, Poppin's Court, Fleet Street, London, E.C.

WIRELESS TELEGRAPHY FOR AMATEURS.



Some Hertzian Wave Apparatus.

Frontispiece.

WIRELESS TELEGRAPHY FOR AMATEURS.

A Handbook on the Principles of Radiotelegraphy and the Construction and Working of Apparatus for Short Distance Transmission.

By R. P. HOWGRAVE-GRAHAM

(*Associate Member of the Institution of Electrical Engineers*).

FULLY ILLUSTRATED.

LONDON:

PERCIVAL MARSHALL & CO.,

26-29, POPPIN'S COURT, FLEET STREET, E.C.

CONTENTS.

PREFACE.

A GREAT deal has been written on the subject of wireless or radiotelegraphy (the latter being the term which I intend to use), but the amateur who wishes to erect a small experimental station for working over short distances must feel himself a rather neglected person; he has been forced to content himself with directions for making simple receivers which will ring bells from one room to another, etc. Unless he has had sufficient time and ingenuity to enable him to construct better apparatus based upon the more general accounts of commercial systems given in text-books and articles, he has not usually got beyond the laboratory stage of experiment.

While I have endeavoured as far as possible to explain the principles of radiotelegraphy thoroughly enough for the experimenter to understand their application to practice, I have avoided needless technicalities, and have devoted most of my space to practical details. Much that is important has

perforce been left out, but, where possible, suggestions have been made indicating to the reader bypaths of thought and experiment which he can explore at will.

Books and articles on workshop methods and recipes are so numerous that it has not been thought necessary to devote valuable space to detailed directions for cutting, shaping, turning, and fixing the various parts of the apparatus, except in cases not likely to have come under the amateur's experience.

Similarly, the painting and varnishing of iron and wood, the lacquering of brasswork, and the polishing of ebonite have all been left to the reader's discretion, and information thereon must be sought elsewhere.

Space has been saved in the letterpress, and confusion avoided in the intricate drawings, by the omission of dimensions; all these can be obtained by measurement from the illustrations, which, in each case, have been reproduced to a definite scale.

Although some very simple apparatus is described hereafter, the reader is urged to attempt the construction of the Lodge-Muirhead receiver, which will amply repay the extra trouble, and is not so difficult to make as might be imagined at first sight of the illustrations. The experiments described on page 85 show what rough apparatus of this type will give good results, while for sensitiveness and certainty

of action the Lodge-Muirhead wheel can hardly be surpassed.

As an instance of this, the receiver shown on page 125 was put aside for more than two months without being touched. At the end of that time the cover was taken off, wires were fixed for the reception of waves, a switch was turned on, the potential divider was adjusted, and messages were received with perfect precision. The oil and the mercury were dusty, and the former seemed to have thickened slightly; but the only noticeable difference in the action of the apparatus was that the potential divider had to be adjusted to give about ·2 volt more than is usually required.

In conclusion, the reader is asked to take special notice of the warning in italics on page 38, as there is a penalty for using radiotelegraphic apparatus without a licence.

It is necessary to bear in mind that the construction and use of apparatus protected by valid patents renders the user liable to action for damages. Such actions, however, need not be feared as long as the apparatus is purely experimental and not used commercially. Those who propose to use radiotelegraphy for business purposes will do well to find out what apparatus is duly protected, since many important patent claims cannot be supported.

My best thanks are due to Dr. Alexander

Muirhead, F.R.S., who afforded me great facilities for studying the construction and action of the Lodge-Muirhead apparatus in commercial use. Though the knowledge gained through Dr. Muirhead's kindness was for use in a more technical publication, it was the simplicity, perfection, and scientific accuracy of the apparatus which led me to abandon the filings coherer with its cumbersome attributes and to commence experiments with the steel wheel.

My thanks are also due to Dr. Muirhead's able and skilled assistant, Mr. Blenheim, who helped me by the elucidation of numberless points in design and detail.

Among others who have helped me are Mr. G. Cook and Mr. A. C. Lock, whose energy and initiative enabled me to carry out with them the series of experiments between Hampstead Heath and Tufnell Park. By the kindness of Mr. Tolchard, I am enabled to give an account, with drawings, of his very neat and simple polarised relay (see page 139). The uninspiring task of correcting, and in many parts editing the proofs, was undertaken by a friend to whom I cannot offer my thanks formally.

R. P. HOWGRAVE-GRAHAM.

City and Guilds Technical College,
Finsbury.

Wireless Telegraphy for Amateurs.

CHAPTER I.

HISTORY AND PRINCIPLES OF RADIO-TELEGRAPHY.

THE OSCILLATORY DISCHARGE.

THE production and properties of oscillatory discharges, and the circumstances under which they give rise to waves which can be used for signalling, can only be outlined here, but have been dealt with at some length in the author's articles in *The Model Engineer*. To these the reader is referred for a fuller account of the subject, illustrated by a series of striking experiments.

Capacity.—When two neighbouring conducting bodies separated by an insulating medium are at different potentials, the insulating medium is subjected to an electrical strain by virtue of which it stores electrical energy. The quantity of electricity stored is proportional to the difference of potential between the plates. Two bodies so placed form a condenser, and the quantity stored in the condenser

for a given difference of potential is proportional to the capacity of the condenser.

The capacity of an ordinary condenser of the Leyden jar type depends on the area of the conducting surfaces and on the thickness and nature of the insulating medium between them; increasing the thickness decreases the capacity.

On removing the wires which give rise to the difference of potential, the state of strain continues until a conducting path is provided between the areas. When this is done, the energy stored in the medium is given up and a current flows round the path equalising the potential of the two plates. The behaviour of the condenser is thus analogous to that of a rubber container which, if filled with water at a high pressure, forces it out by its own elasticity when the pressure is removed and a path provided.

Self-induction.—When the value of the current in a wire is altered, the magnetic field formed by the current changes, and, in doing so, induces electro-motive forces in the wire. These are always in such a direction as to oppose the original change; thus, if the current be increased from zero to some definite value, the fields set up during the increase induce electro-motive forces which tend to prevent the flow. Similarly, a decrease in the current is opposed by induction effects which tend to maintain the flow at its original value. This induction of electro-motive forces in a wire by changes in its own current is known as self-induction. It causes the current to behave very like a flowing liquid which has inertia. If the water flowing in a long pipe be suddenly stopped by turning off the

tap, the column of liquid tends to keep moving by virtue of its inertia, and the energy stored manifests itself by a hammering sound in the pipe. Again, if the tap be suddenly turned on, careful observation will show that it takes a fraction of a second for the flow to reach its final value.

The Oscillatory Discharge.—Figs. 1 and 2 show by a very neat analogy, completed by Prof. Northrup, how the effects of self-induction and capacity can be combined so as to set up electric oscillations, which surge in alternate directions round a circuit.

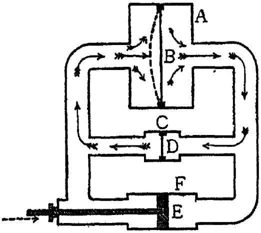


FIG. 1. FIG. 2.

In Fig. 1, A is a box connected by pipes with the small box C and with the cylinder F, in which a piston E is fitted. A rubber diaphragm B is stretched across the middle of the box A, and a small diaphragm of non-elastic brittle material D across the box C. Each of the diaphragms completely divides its box so that no water can get from one side to the other. If now a gradually increasing pressure be applied to the piston in the direction of the dotted arrow, the elastic diaphragm B will bulge to the left, as shown by the dotted line, until a

pressure is reached at which the brittle diaphragm D breaks down and provides a free passage for the water. If the friction be not too great, B will then straighten itself, forcing a rush of water in the direction of the arrows.

By the time B has reached the central position, the water will be in rapid motion and its inertia will carry it on so that it will overshoot the mark and rush into the left-hand side of A, causing the diaphragm to bulge to the right. A will once more straighten itself, producing a rush in the opposite direction to that of the arrows, and so inertia and elasticity will alternately come into play, producing oscillatory surgings of water until the energy originally stored in the stretched rubber has been expended in overcoming the friction of the pipe.

In Fig. 2 we have the secondary of the induction coil F raising the potential difference between the two surfaces of the condenser A, and producing an electrical "stretching" of the glass between them, more and more energy being stored by A until a moment comes when the spark-gap C gives way and allows a rush of electricity to pass round from one side of the condenser to the other. Self-induction prevents this rush from being instantaneous, and it attains its maximum value when the potential of the two condenser surfaces has been equalised. Self-induction also tends to keep the current flowing when once it has been established; accordingly, the current overshoots the mark and charges the condenser in the opposite direction. Thus, capacity and self-induction come into play alternately, each rush being less than the last, until the oscillations die away and the whole is at rest.

Frequency.—The rapidity with which the surgings in the water circuit (Fig. 1) follow upon each other is decreased by increasing either the elasticity or the inertia; similarly in the case of a weighted spring, weakening the spring, or increasing the mass at its end, increases the period of each swing so that there are fewer in a given time.

The time in secs., of one complete swing—that is, from the central position to one side, to the opposite side, and back to the central position—is known as "the periodic time"; the number of such swings taking place in one second is called "the frequency."

Increasing the capacity or electrical stretchability of a circuit increases the periodic time and decreases the frequency, a similar result being produced by increasing the self-induction or electrical inertia.

The capacity can be increased by enlarging the effective area of the condenser, and in other ways previously indicated, while the self-induction can be raised by using coils instead of straight wires, thereby increasing both the amount of magnetism and its inductive effect. If an iron core be inserted in the coil the magnetism is provided with an easier path, and the self-induction, which is proportional to the square of the number of turns, is still further increased; but the waste of energy through magnetic hysteresis (see text-books) and induced currents in its mass is so serious at high frequencies, that, however finely the core be laminated, it is, under these circumstances, worse than useless.

The frequency of oscillation of Leyden jars discharging through straight rods, simple coils, etc., varies from a few hundred thousand vibrations to a million or more per second.

Amplitude.—The amplitude of a vibration is the maximum value to which it rises on either side of the position of rest. Thus, if a weight vibrating at the end of a spiral spring moves over a total distance of 6 ins., its amplitude of vibration is 3 ins.; an alternating current which rises to a maximum value of 10 amps. has an amplitude of 10.

An oscillatory condenser-discharge gradually dies away and, therefore, has a diminishing amplitude which eventually falls to zero.

It must be borne in mind that the frequency is an expression of the *rate* at which the vibrations take place. Thus, there may be two or twenty oscillations before the swingings die away; but if each takes one-millionth of a second, the frequency is a million per second.

Let us consider the action of a Leyden jar which is charged by an induction coil every time the interrupter breaks the current, and is arranged to discharge across a spark-gap and through a turn of wire, as in Fig. 2. Each time a spark passes across the gap there will be a group of oscillations round the turn, each oscillation being less than the last, until they die away to nothing. The rate at which the amplitude decreases depends on what is called the "damping of the circuit." The damping is the rate of loss of energy by the oscillating charge, and there are four ways in which this loss takes place:

(1) By the generation of heat in the insulating material of the condenser (dielectric hysteresis).

(2) By the generation of heat in the resistance of the circuit.

(3) By electromagnetic and electrostatic induction of currents in neighbouring conducting bodies.

(4) By the generation of free electric waves travelling out into space.

The latter is not very considerable in the case of Leyden jars and closed circuits, but is the most important of the four in radiotelegraphy. If all four could be eliminated the charge would oscillate for ever.

If the resistance be increased beyond a certain value which depends on the capacity and self-induction, the charge will not oscillate at all, and thus resembles a weighted spring which, if displaced in some viscous substance such as treacle, returns slowly to the position of rest without vibrating.

Induction and Self-induction Effects.—At very high frequencies the ordinary induction and capacity effects of alternating currents are enormously increased, and startling results follow.

A 100-volt lamp can be made to burn brightly though apparently short-circuited by a foot or two of thick copper rod; lamps can be lit at a distance of 2 or 3 ft. by induction between coils of five or six turns, and discharges at several hundreds of thousands of volts can be produced by an induction coil wound with only an ounce or two of secondary wire. These discharges can be taken to the body and made to issue from the fingers; they can also be conveyed along a single wire with no return, and then transformed down so as to light a lamp.

Skin Effect.—For reasons which will not be discussed here, oscillatory currents are almost entirely confined to the surface of the conductor which

carries them. This must be borne in mind in the construction of aerials, etc., for radiotelegraphy.

ELECTRIC WAVES.

None of the electromagnetic or electrostatic induction effects described above are due to true electric waves. When an ordinary condenser is charged, almost the whole of the electrostatic strain is situated in the glass between its coatings; but for

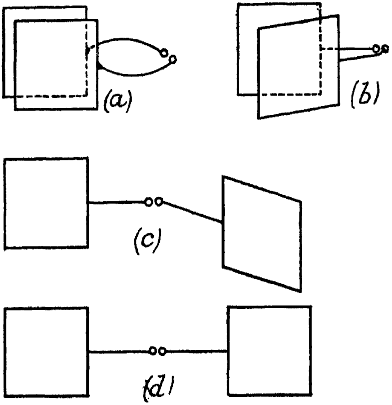


FIG. 3.

the production of true waves travelling out from their source and never returning, the electrostatic effects must be free in space as well as the magnetic fields formed round the wire.

Fig. 3 (*a*) shows two plates placed parallel and near together so as to form an air-condenser; the plates are provided with a pair of rods and a gap through which they can discharge.

The electrostatic strain is almost entirely confined to the space between the plates; but if we now imagine them to be separated a little more, as in *b*, some of the lines of strain will stray out into the region round the plates. On separating them more and more widely, as in *c* and *d*, the strain lines will eventually spread out in increasingly far-reaching curves from plate to plate, until they are entirely free in space and capable of forming true waves in conjunction with the magnetic whirls round the rods. At the same time, the capacity and therefore the energy storage will have been enormously reduced, and, as a consequence, the frequency of oscillation will be much higher than it was in the first case.

The magnetic and electric fields being thus free to travel out into space together, the pair of plates with its straight rods and gap has become a radiator, and, in fact, is exactly the apparatus used by Prof. Hertz, in 1888, for his historic experiments on the production and properties of electric waves. Hertz was the first to attempt seriously what Prof. Clerk Maxwell in 1867 had prophesied would be accomplished sooner or later. Maxwell had deduced his prophecy from abstruse mathematical considerations, and had predicted the properties of the electric waves, which he said would be found to be identical with those of light and heat. Heat, light, and Hertzian radiations are, in fact, electric waves of different frequencies.

Hertz's oscillator, as described on page 39, gives waves at a frequency of about 100 million per second. One of the smallest Hertzian oscillators which has been made gives about 30,000 million per second.

The slowest heat wave has a frequency of about

10 billion per second; that of the most rapid light wave being about 800 billion; while beyond this, there are invisible rays up to 1,600 billion per second.

Hertz verified all Clerk Maxwell's predictions by experiments made with the somewhat unwieldy apparatus which the dimensions of his transmitter and detector necessitated; subsequent workers have found other proofs, and, using far more delicate apparatus, have been able to make accurate quantitative tests.

The detector used by Hertz was simply a large circle of wire, at one point in which there was a gap between two very small spheres. A screw adjustment was used to vary the distance separating the balls, between which the electro-motive forces induced by the waves manifested themselves in the form of minute sparks.

Hertzian waves are invisible and can pass through insulating substances, though they are stopped by conductors which partly absorb and partly reflect them. They can be brought to a focus by means of parabolic mirrors, and can be refracted by prisms and lenses of pitch, ebonite, sulphur, glass, etc. They can also be polarised, doubly refracted, and made to produce interference effects. Attempts which have been made to direct the waves to great distances in parallel beams by using parabolic mirrors have been unsuccessful. We must, therefore, consider every ordinary oscillator as sending out waves of equal strength in all directions, so that anybody with suitable apparatus can pick them up unless special precautions are taken.

In about the year 1890, Prof. Edouard Branly

investigated the effect of Leyden jar discharges on metallic powders, the resistance of which was found to be greatly decreased after the passage of sparks in the neighbourhood. Others before and after him made similar experiments, some knowing how to account for the effects and others working in the dark.

In 1895, Sir Oliver (then Dr.) Lodge detected waves from an oscillator over a distance of about 40 yards, using a filings tube coherer, a galvanometer, and a cell. The coherer, which is described later on in detail, consists, broadly speaking, of one or more imperfect contacts, the resistance of which is considerably lessened under the influence of oscillatory electromotive forces induced in the circuit by waves.

The simplest form consists of a tube containing metallic filings into which two wires are thrust so that their ends nearly touch. To restore the coherer to its original insulating condition after it has become conducting, it is only necessary to shake up the filings by giving the tube a slight tap.

Sir Oliver Lodge, whose researches and inventions in connection with electric waves and radiotelegraphy are second only in importance to those of Hertz himself, was the first to study and improve upon the simple coherers used by Branly. As early as 1894 automatic clockwork tapping devices were introduced by Sir Oliver, who carried on signalling at a distance through walls, etc.

In 1894, Dr. Alexander Muirhead, foreseeing the importance of this method of signalling, actually arranged a coherer, a clockwork tapper, and a siphon recorder for the purpose, and obtained excellent results.

In 1895, Prof. Popoff (of Cronstadt) used and described apparatus in which an ordinary lightning conductor was employed for receiving waves, a coherer being inserted between it and the earth. Across the coherer a cell was connected in series with a relay, the contacts of which formed part of a circuit containing a bell and a battery. The hammer of the bell was so placed as to tap the coherer and restore it to an insulating condition. With this apparatus Popoff detected waves from distant lightning flashes, and also from oscillators.

In 1895, Captain Jackson, R.N., carried out a series of very interesting experiments, and succeeded in signalling between ships.

In 1896, Mr. Marconi took out a patent for "Improvements in Transmitting Electrical Impulses and Signals and in Apparatus therefor." This patent claims the previously known coherer and tapping device, and also one or two novelties of a minor kind, but the real invention appears to have been the use of a long vertical wire attached to one side of a spark-gap, the other side being connected to earth.

In recent years the earth-connection has been conclusively proved by Sir Oliver Lodge to be actually a disadvantage. The patent included some very real improvements in the design of the coherer; these must have been the result of careful and praiseworthy experiments. Shortly afterwards, commercial enterprise and popular non-technical journalism set people agog to know more about the "new" marvel which had been slowly developing since 1888.

The world and his wife were awake, and, like the

princess in the fairy tale, they were enamoured of the first object presented to their waking vision. Years of patient toil and research by some of the best scientists were nothing to them; they had discovered the marvel and they had discovered its "discoverer." Ten years have passed, and numbers of excellent systems are now at work in different parts of the world. One of the best of these, developed by Sir Oliver Lodge and Dr. Alexander Muirhead—who were actually signalling by Hertzian waves before the "great awakening"—is doing excellent work and is quietly and steadily gaining ground; but the spell still holds the world and his wife, and they look troubled and suspicious at the mere mention of a new love. Sir Oliver Lodge was the first to see the importance of syntony in radiotelegraphy, and all who now use syntonic systems are therefore indebted to him. Syntony, or tuning between a transmitting and a receiving aerial, is a state of adjustment of their capacities and self-inductions which causes their natural periods of oscillation to be identical. When two aerials are thus tuned to one another, the receiving aerial will respond to the transmitting aerial more easily and with greater certainty than it would if their natural periods were different.

If perfect tuning is attained the gain is threefold:

(1) The possible distance of action between tuned aerials is greater than between those which are untuned; that is, the system is more sensitive.

(2) Untuned hostile aerials are unable to receive the messages unless they are very near to the transmitter.

(3) Untuned aerials are unable to make the tuned aerial receive their messages unless again they are close at hand.

The two last-named advantages are dependent on certain other conditions besides mere syntony. The most important of these is that the tuned aerials must be so arranged as only to respond with ease to long and persistent trains of comparatively feeble waves, and this condition is satisfied by means which cannot be entered into here.

To aid the reader in understanding the principle of syntony, his attention is drawn to the analogous behaviour of two tuning forks of exactly the same pitch. If one is sounded near the other, the latter will respond by beginning to vibrate in unison; but it is difficult to make any sudden noise—however violent—affect it, and it is impossible to make it respond by sounding a note of different pitch in its neighbourhood. For successful syntonic working, aerials of large capacity must be used, various, and somewhat difficult, means of adjustment being provided. As these are probably beyond the average amateur experimenter, and certainly beyond the scope of this book, the author will not attempt to describe them.

Lodge-Muirhead Aerials.—Sir Oliver Lodge maintained from the beginning that the ideal radiator must be a symmetrical oscillator, free in space like the original arrangement of Hertz, and careful quantitative experiments recently made by him, in conjunction with Dr. Muirhead, have shown that this is actually the case. Accordingly the aerial arrangements now used in their system are as shown in the diagram, Fig. 4, and described in detail on page 42.

The networks can be made as large as is desired; the greater their area is the greater will be their capacity, and therefore, also, the greater will be the energy which can be stored in them and the longer the distance over which the messages can be sent.

Oscillation Transformers.—The old method of connecting the coherer between the aerial and the earth is not by any means the best. The coherer

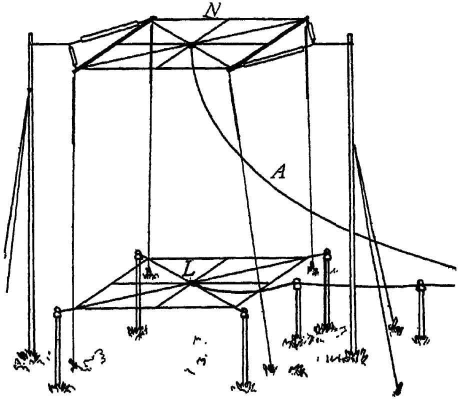


FIG. 4.—Diagrammatic View of Lodge-Muirhead Aerial.

is a piece of apparatus which is operated by potential difference, and this is greatest at the top of the aerial, where connection for this purpose cannot be made. If the coherer were taken to the top of the aerial, it is obvious that no difference of potential could be produced between its terminals, not even by taking a wire down to the earth. Such wire would immediately act as a second receiving conductor with its summit

at the same potential as that of the original aerial, so that the difference of potential between the coherer terminals would be zero. Inserting the coherer in the bottom of the aerial where the wave-induced currents are greatest breaks the continuity of the aerial, rendering proper tuning impossible, and causing the coherer to be actuated by secondary or overtone vibrations. The same difficulties in a slightly different form are met with in the case of the non-earthed Lodge-Muirhead aerial.

In 1897, Sir Oliver Lodge patented an oscillation transformer, the primary of which is inserted where the current is greatest, a free path being thus provided for the oscillations; the secondary coil is connected to the coherer, which is operated therefore by induced potential difference, interference with the surgings in the aerial being avoided.

This device was also patented by Mr. Marconi in 1898.

As condensers must be provided and accurate syntony established between various portions of a receiving circuit containing an oscillation transformer, the author will refrain from giving further particulars of this arrangement for reasons already stated.

Detectors used in Radiotelegraphy.—There are a number of other detectors besides those of the coherer type. In some the induced oscillatory currents are made to heat a wire, thus altering its resistance; in others use is made of their effect on magnetised iron; and in others again the oscillatory potential differences are made to break down the polarisation film on a fine electrode immersed in a liquid. Space does not permit a full discussion of

these, but the author may point out that they can be usefully divided into two classes: (1) Detectors which are current-operated and only need to be inserted in the aerial. (2) Detectors which are voltage-operated and for best working require an oscillation transformer, resonator, or other device, for converting the currents in the aerial to the potential differences required for the detector.

Effect of Natural Conditions on Signalling.—The difficulty of signalling is greatly increased by the intervention of rising ground, though Prof. Lodge and Dr. Muirhead have shown that no ordinary obstacles make the establishment of communication impossible. With aerials only 42 ft. high they have sent messages with perfect success from one side to the other of Snowdon, the horizontal distance being 19 miles and the greatest intervening height 3,200 ft. It is impossible to give figures for guidance as to the power required for working over various contours of land, but where possible the stations should be erected on hills and the intervening ground should be flat.

Oversea work is far easier than overland. This is not the place for a discussion of the various reasons which have been advanced to account for the way in which the waves seem to travel over, round, or through obstacles, neither can the differences observed between night and day be considered. Signalling over great distances is always easiest at night-time, but the effect is hardly noticeable within the range over which amateurs are likely to work.

CHAPTER II.

THE POULSEN SYSTEM OF GENERATING ELECTRIC WAVES FOR RADIOTELEGRAPHY.

UNTIL November 1906, the only known methods of producing alternating currents at very high frequency were by means of rotatory or reciprocatory dynamos or by the sudden discharge of condensers through inductive circuits. The first-named method gives an unbroken series of undamped oscillations, which differ from ordinary alternating currents only in the excessive frequency of their vibration. By means of specially designed high-speed alternators, with a large number of very small poles, Mr. Tesla has succeeded in producing currents at 25,000 cycles per second, and has shown the greatly increased importance which induction and capacity assume at high frequencies.

The production of oscillations by condenser discharges has been dealt with already, and we have seen that when waves are emitted in short damped groups, as in spark-telegraphy, the radiation of energy is very vigorous while it lasts, the period of inactivity between each group and the next being very long in proportion to the period of activity; thus the average rate of energy-radiation in a second

is very small in comparison with the high value at the commencement of a wave-train.

With the recent rapid development of radiotelegraphy, the importance of maintaining communication between stations without interruption or interception by neighbouring installations has greatly increased; as a consequence, the great attention given to the problems of syntony or tuning has led to a high pitch of perfection in this respect. It has long been realised, however, that if some practical method of producing waves in a continuous stream could be devised, radiotelegraphy would be revolutionised and the present system of spark-telegraphy would become a thing of the past.

If we return to the tuning-fork analogy used on page 22, we find that to obtain accurate and vigorous selective response it is not merely necessary to sound a note of exactly the right pitch, but the sound must be more or less prolonged so that each vibration arriving from the source of sound shall reinforce the vibrations in the responsive fork, and give a true, cumulative effect. If the source of sound is itself a tuning-fork which is set in action by a blow, its vibrations will die away, and as the successive tuned impulses beat upon the responsive fork and increase its amplitude of vibration, they themselves are decreasing in vigour until a moment is reached when the usage of energy in the receiving fork is balanced by the supply from that which is transmitting; this is the moment of maximum amplitude in the series of induced vibrations, and from this moment onwards they must decrease until the combined system is at rest.

The longer the train of waves from the transmitting

fork is made the greater will be the maximum amplitude of the induced vibration, until, if the transmitted sound-waves are made continuous by sounding the fork with a violin bow, the amplitude of vibration attained by the receiving fork will rise to a considerable value, at which it will remain as long as the train of waves is maintained.

Steadily maintained sound-waves enable energy to be transmitted from one fork to another at a greater average rate than is possible if blows are applied at intervals, but what is more important, they produce a far greater cumulative effect on an accurately tuned fork and they give a far greater precision and selectivity of tuning than would otherwise be attainable.

Similarly, in spark-telegraphy the tendency has been to arrange the apparatus to give long trains of waves of gradually diminishing amplitude, even when this has involved weakening the instantaneous value of the radiation-energy. At a critical moment, when spark-telegraphy has been brought to a state of great perfection, the world has been startled by the announcement of a method of producing a continuous stream of electric waves just as the bowed tuning-fork gives a continuous stream of sound-waves.

The new system introduced by Mr. Valdemar Poulsen is a development of certain discoveries described by Mr. Duddell in 1900. Without any desire to detract from Mr. Poulsen's inventive ingenuity and painstaking experimental work, we may at the same time express a hope that the non-technical press and the public will join with Mr. Poulsen himself in recognising the claims of the

brilliant experimenter who, stopping where Mr. Poulsen began, was nevertheless the discoverer of the principle involved and foresaw the possible importance of his work in the future history of radiotelegraphy.

In 1900 Mr. Duddell described some remarkable experiments on the electric arc, the most important in connection with the present matter being as follows:—When a condenser and self-induction coil were connected in parallel with an arc supplied by a direct current, oscillatory currents were set up round the circuit under certain conditions. These currents surged back and forth through the coil and the arc and into and out of the condenser at a frequency which was found to depend on the values of the capacity and the self-induction. The vibrating currents through the arc produced corresponding changes in its temperature, and therefore in its pressure, and the beats thus transmitted to the air gave rise to a musical note, the pitch of which could be varied by adjusting the condenser and the coil.

By these means Mr. Duddell obtained frequencies up to 30,000 or 40,000 per second, but for radiotelegraphy such vibrations were of as little use as those produced by Mr. Tesla's high-frequency alternators. The reason for this is that the natural period of oscillation of the aerial must be exactly equal to that of the alternating currents used; that is, the aerial must be syntonised. At comparatively low frequencies the capacity and self-induction required are so great that a practical and convenient aerial cannot be constructed. Fig. 5 shows the connections used by Mr. Duddell.

In the course of a series of remarkable experiments, made with the object of increasing the frequency of the oscillations so as to bring them within the range of wave lengths suitable for radiotelegraphy, Mr. Poulsen has arrived at an arrangement of apparatus which gives oscillations up to a million per second. The first step made was to cause the arc to burn in some other gas than air. One

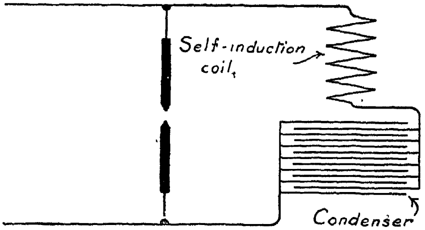


FIG. 5.—Connections used in Duddell's Experiments.

of the early devices was to surround the arc with alcohol vapour by burning a spirit lamp under it, but coal-gas and hydrogen were found to allow of higher frequencies than alcohol vapour.

Mr. Poulsen has not yet arrived at any very definite conclusion as to the reason for this action of hydrogen, but suggests that it is "intimately connected with its peculiar physical properties. The high atomic velocity of hydrogen results in a great thermal and electrical conductivity, which is probably the chief factor involved in the specific influence exerted by this gas."

The results are further improved by placing the arc in a strong magnetic field, the potential

difference of the electrodes being thereby greatly increased in proportion to the length of the arc. An arc only 3 mm. long may be maintained with 440 volts between the electrodes. This enables the self-induction in the oscillation circuit to be considerably increased in relation to the capacity, and therefore raises the potential difference between the coatings of the condenser.

Mr. Poulsen also claims a greater general efficiency for the system when the magnetic field is used, and says that it causes the arc to be more geometrically defined and the oscillations therefore more constant. The windings of the electro-magnet used to create the field may be connected in series with the arc.

The effect is still further increased by using an anode of copper and a cathode of carbon; and when large currents are used, the former is further kept cool by being made in the form of a tube closed at the working end and fed with cold water, which enters at the other end and leaves by a pipe inserted in the side of the tube. The end of the anode at which the arc is formed is fitted with a ring of copper, which can be renewed if necessary.

In some cases, when both electrodes are of carbon, their ends are very accurately turned to sharp angular edges, and they are slowly rotated so that any change due to the very slight deposition of carbon which takes place is remedied by the presentation of a new part of the edge. The peripheral speed need not be more than ·05 mm. per second. A powerful magnetic field at right angles to the arc forces it upwards so that it bends in a

steep arch over the gap. Fig. 6 shows the electrodes of an arc the anode of which is water-cooled and provided with a renewable ring.

The arc may be enclosed in a metal chamber, the ends through which the electrodes pass being of marble or other insulating material.

The gas (preferably coal-gas, or hydrogen carburetted by passage through a reservoir of naphtha) is led into a chamber immediately beneath the arc, or even through a channel in the anode. Owing to changes produced in the gas by the oscillations a continuous stream is passed through, but the consumption is small.

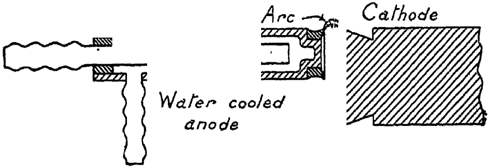


FIG. 6.—Arc with Water-cooled Electrode.

The energy which, at a given tension of the feed-current, can be transformed into electric oscillation decreases as the rate of oscillation increases, but for a given number of oscillations it increases directly with the damping in the oscillatory circuit up to a certain point. Beyond that point the decrease is very rapid. Up to a certain point also, the energy increases with the current passing through the arc.

By increasing the number of arcs in series, the power can be considerably augmented; but this has not been found necessary in practice.

With a feed-current at a voltage of 440, Mr. Poulsen has obtained an oscillatory power of 1,200 watts, at a frequency of about 160,000 per second; with the same arrangement an increase of the frequency to 240,000 reduced the power to 900 watts.

In his famous demonstration at Queen's Hall, Mr. Poulsen showed a remarkable series of experiments, illustrating the abundance of oscillation energy available from the arc and the extreme accuracy of selective tuning which the method supplies. At a distance of about a yard from the radiating circuit, a vertical resonating coil, about 18 ins. high and 6 ins. in diameter, connected to a vacuum tube, was accurately tuned and caused the tube to glow vigorously. On the approach of a conducting body, such as the operator's hand, the capacity was changed sufficiently to throw the coil out of tune and extinguish the glow of the tube.

A larger coil emitted a very powerful brush discharge which appeared to sprout from the top, and it was most remarkable to see this die down almost to nothing on the approach of Mr. Poulsen's hands.

Astonishing induction effects were also produced in a single turn of wire which was connected to a bank of four or five ordinary (apparently 100-volt) glow lamps; these glowed at full brightness when the turn of wire was placed a short distance above the exciting coil, and when it was lowered a few more inches they were burned out. A single short-circuited turn of copper held above the coil was rapidly raised to a bright red heat and then

fused. The well-known brush discharge effects were produced by means of a Tesla coil with a secondary of 3,000 turns, but when the discharge distance was reduced their place was taken by a 10-in. or 12-in. flaming arc of irregular and variable shape, and somewhat similar to the flame discharge obtained from an ordinary high-voltage alternating transformer. A noticeable feature throughout was the quietness of the discharges. The roaring and crackling of the ordinary Tesla discharge, which consists of a rapid series of momentary and violent effects, seemed to be replaced by a slight rushing noise somewhat resembling a stream of burning gas. The flaming arc did not emit a musical note, as do those which are produced by currents at ordinary frequencies; this, of course, is because the periodicity is above the limits of human audition.

Mr. Poulsen proceeded to describe various arrangements for conveying the energy from the oscillating circuit to an aerial used for-wireless telegraphy, and briefly discussed the possible methods of obtaining the changes necessary for signalling by the Morse code. He pointed out that to signal by making slight changes in the frequency of the circuit would involve the use of two wave-lengths for each station, and that this would halve the number of stations which could work simultaneously without interference in a given neighbourhood.

Among other devices for this purpose, Mr. Poulsen mentioned short-circuiting a series resistance by means of the signalling key, and altering the length of the arc.

The receiving circuit must be accurately tuned,

and damped as little as possible, so that full advantage may be taken of the resonance principle. The wave detector may be arranged so that it only intermittently forms part of the oscillation circuit. By this means the damping which would be occasioned by the permanent introduction of the detector is avoided, and the circuit is allowed to get well into oscillation before its accumulated energy is given up to the detector.

The very simple device for attaining this object s known as the ticker, and consists of a small electromagnetic vibrator, or a toothed wheel in light contact with a spring. Thus, almost any known wave detector can be made to work with this system if a ticker be provided.

The sharpness of tuning with which stations on this system may be worked without mutual interference is in practice about 1 per cent. For instance, two stations transmitting at wave-lengths of 600 and 606 metres over the same territory will act without interference on two distant receiving stations which are close together.

Three messages have been simultaneously received on one aerial, the difference in the wavelength only amounting to between 3 and 4 per cent. As more energy is obtained with the greater wave-lengths, these are used for long distance working, the higher frequencies being reserved with the lower aerials for smaller work.

In June, 1905, signals were received at nine miles after experimenting for a couple of days; this distance was afterwards increased to twenty-seven miles, and communication was established on the same day. Signals were next sent across the

whole width of Denmark—a distance of nearly 180 miles—communication being effected, as before, on the day of completing the installation erected for the purpose. The signals were perfectly intelligible even with an energy-consumption of only about 800 watts. The energy radiated was about 100 watts. The potential difference between the aerial and the earth was then no more than a few thousand volts, and the wave-length was from 700 to 100 metres. The signals were afterwards greatly improved by using a stronger magnetic field at the arc, the radiating power being about 400 watts.

On one occasion the apparatus at Esbjerg was fitted up for receiving signals by *spark-telegraphy*; the result was a confused and unreadable jumble of signals from various stations, but reversion to the use of the arc instantly restored the communication without the slightest interference from elsewhere. Recently, perfect and unbroken communication has been kept up between Copenhagen and North Shields, a distance of 530 miles, nearly a quarter of which is overland; the mast used was only 100 ft. in height.

The field of speculation and experiment opened up by this discovery is vast, and startling developments may be expected, not only technically, but commercially. Wireless telephony, which has hitherto seemed a most remote possibility, now looms large on the horizon, and transatlantic signalling at a comparatively small cost will certainly become possible. Other investigators besides Mr. Poulsen have been experimenting with success on similar lines; it remains to be seen whether their

methods of producing undamped radiations can compete with his.

Existing systems of wireless telegraphy must pass away or suffer great changes financially and otherwise, yet the great principle of syntony, without which Mr. Poulsen's system is useless, can be claimed by Sir Oliver Lodge alone. How far the new system will be dependent on his patent rights over apparatus used for tuning will appear in due course, but no impartial person who is intimately acquainted with the history of wireless telegraphy would be sorry to see Sir Oliver Lodge reap the long deferred fruits of the splendid research and experiment for which others have too often taken the credit.

CHAPTER III.

PRACTICAL RADIOTELEGRAPHY.

PURPOSE AND RANGE OF APPARATUS.

BEFORE setting to work upon the construction and erection of apparatus, the reader must first come to some decision with regard to the use which he desires to make of it. For instance, he may be content with apparatus which will ring a bell at the far end of a room or passage, or he may further wish to convert such indications into intelligible signals made visible or audible or recorded on a strip of paper. A more ambitious reader may wish to signal over greater distance, with sending and transmitting apparatus at both stations. It is, therefore, the author's purpose to describe transmitters and receivers of two or three different types, so that the reader has as much choice as can be offered to him within the available limits of space.

If anything in the nature of a station is contemplated, even for working over a short distance, a licence must be obtained. Licences for experimental work can usually be obtained on application to the Postmaster-General, and for these no charge is

TRANSMITTING APPARATUS.

OSCILLATORS AND AERIALS.

A good oscillator for general experimental work is the original Hertz radiator, briefly described on page 17, and it is constructed with ease and cheapness in the following way:—Two squares of 16-in. edge are cut from fairly stiff sheet zinc, and two 13-in. lengths from ¼-in. brass rod. Each rod is fitted with a ball of brass ½ in. diameter, which may be fixed either by screwing the rod into it, or by drilling it to a depth of ¼ in. and forcing or sweating the rods into the hole. The balls can be procured solid, or they may be turned from ½-in. brass rod. If several are required, they may be cast to pattern and turned afterwards. Hollow balls of spun brass can also be obtained for a few pence at Millward's, in Albemarle Street, Clerkenwell; they are known in the trade as "beads," and are made in various sizes up to 2 or 3 ins.

Each rod is now sweated on to one of the plates at the centre of one of the edges, a flat being filed on the rod for a length of 1½ ins. in order that there may be a good gripping area for the solder.

There is no need for great care in insulating the plates, which therefore may be supported by a pair of wooden blocks cut longitudinally with a saw to a depth of about 1 in. The blocks, which can be painted, or stained and varnished, may be made about 8 ins. in length, 6 ins. in width, and 3½ ins. in depth. When the oscillator is required for use, the plates are pushed into the slits, in which they should fit fairly tightly.

The main dimensions of this oscillator are almost

exactly those of one of Hertz's original designs, in which the plates were 40 cms. square, the distance between them being 60 cms. (see Fig. 7).

For producing more vigorous effects, larger and more powerful oscillators of the same type and general proportions may be constructed at will. A Hertz oscillator is shown at the back in the photograph reproduced in the frontispiece.

A pair of rods, 2 or 3 ft. long, with brass spark-balls at the end, may be used as a radiator, though

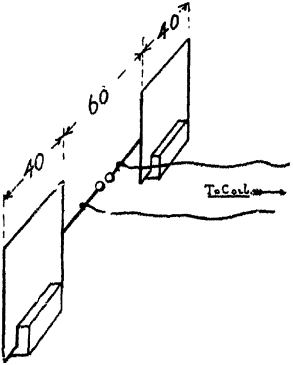


FIG. 7.—Dimensions and Method of Support of a Hertz Oscillator

the capacity—and therefore the energy—is smaller than in the case of the Hertz oscillator.

The Sparking Surfaces.—The sparking surfaces of all laboratory oscillators must be carefully and frequently polished, as the slightest roughness or dulness, due either to pitting by the spark or to other causes, very seriously reduces the energy of radiation. The reason for this is that only very little energy of charge is stored in oscillators of small capacity, and

it is necessary that the spark shall snap across the gap with great suddenness carrying the whole of the charge with it in a violent rush. If the sparking surfaces are rough, some of the charge spits off from the points and projections on the surface, and a considerable amount of the energy is lost before the actual spark takes place. Probably also the spark is not sudden when it does come, but is preceded by a sort of brush or preliminary discharge, which gradually lowers the gap resistance instead of very suddenly reducing it from infinity to a comparatively low value.

For this reason the Lodge ball-oscillator, the capacity of which is very small, requires a higher polish than the Hertz oscillator; while Prof. Bose's radiator, with its central ball only 1 cm. in diameter, requires even greater care in this respect. This is an additional reason for using small spark coils with laboratory radiators (see page 62). On the other hand, larger radiators with greater capacity give no trouble in this respect, and the spark balls of aerials such as the one described below may be allowed to get quite rough without any apparent decrease in efficiency.

Arrangement of Aerials and Spark-gaps.—Where the radiation required is greater than that obtainable from a Hertz oscillator, it is advisable to use one of a vertical type, which may be as high as is convenient. Vertical oscillators supported by masts or other means at a considerable height above the ground, are known as aerials, but are not essentially different from the form used by Hertz (see page 17).

If the apparatus shown in Fig. 7 be insufficient for any given purpose, a transmitter of the "aerial"

type must be adopted, and its height may be anything from 5 or 6 ft. to 30 or 40 ft. One such aerial must be erected at both the sending and the receiving stations, and at each station *the one aerial* serves either for transmission or reception.

The author proposes to give general directions and hints for the construction and arrangement of aerials, and then to give full details and particulars of one station of an installation erected by him for signalling to a distance of 1¾ miles. It must be borne in mind that two aerials intended to work together should be as nearly as possible of the same design and dimensions, and that there will be therefore no gain in describing both of these stations in which only the details of staying and fastening the poles, etc., were different.

The best general type is undoubtedly that adopted in the Lodge-Muirhead system, more especially as it is far more easily erected by the amateur than single wire aerials, which, for the same range of working, require to be raised to great heights. It is also far easier to manipulate than fan or cone aerials, and can be raised or lowered at will, and even dismantled, rolled up, and packed away with ease.

Fig. 4, p. 23, gives a diagrammatic representation of the general arrangement, which consists of a rectangular (preferably square) network of copper wire N, suspended horizontally at a considerable height from the ground with a wire or assemblage of wires, A, attached at its centre and brought down to the apparatus at or near the ground level. A second wire from the apparatus is connected to a similar lower capacity-area or network L, and this is by preference raised 2 or 3 ft. above the earth on insulators. If this be inconvenient, it may lie on

the surface of the ground, and if, as is often the case in amateur installations, it is impracticable to use a second capacity-area at all, an isolated row of railings, or a large iron gate, is preferable to an earth connection through gas or water pipes, especially if the aerial be raised on the roof of a house containing such pipes.

The network shown in the diagram is provided with stiff rods at each end, and ebonite insulators are inserted between the ends of the rods and the rope by which the aerial is hung. Guy-ropes are attached at the four corners, and are all insulated from the network by rods of ebonite. The lower capacity-area and the wire running from it to the apparatus are supported on porcelain or other insulators well raised above the ground. Large aerials are usually hung from four corner poles, and do not then require stiffening rods at the ends. All connections should be thoroughly good, loose joints causing serious loss of energy.

If a second network of copper on or near the ground be used, a good connection made at the centre is quite sufficient; but if it be made up of strips of iron netting, galvanised or otherwise, several copper feeders should be soldered together in a bunch and attached at various points. If the earth connection be made to a leaden or galvanised iron outhouse roof, a similar method is advisable; if to iron railings or gates, two or three copper feeders should be attached at widely separated points, connection being best established in either of the following ways:—(*a*) By hammering ordinary brass terminals into holes made in the iron with a hand drill, the holes being slightly smaller than the

diameter of the terminal shanks; (*b*) by cleaning all rust and paint from a suitable place and fixing an ordinary battery clamp in such a way as to make a thoroughly good contact.

The aerial network must be as high as possible, the cheapest and easiest way being to sling it between poles on a high roof (which, however, must be safe to work upon, and should be provided with planks if it be covered with slates). The aerial must be mechanically secure, and requires some simple gear for hoisting it up and letting it down. It must also be carefully insulated. The aerial wire leading from the network to the apparatus should be of at least two strands of No. 12 copper, which need not be twisted together as long as they make thoroughly good connection with the centre of the network. Where large powers are available, three, four, or even more strands are preferable.

The aerial wire or wires must be brought down to the apparatus in such a manner as to hang well away from any buildings, trees, or other objects, the distance of clearance being nowhere less than two or three feet, and, if possible, considerably more.

Special care must be exercised in keeping the wire as far as possible from any pipes, lightning-rods, lead roofs, or other conducting bodies, not only in order to avoid leakage by brush discharge, but because such objects short-circuit the electrostatic field, or, rather, cause it to concentrate between themselves and the wire instead of extending outwards into space in all directions.

If no roof is available, poles must be fixed by other means—two for small networks, four for larger areas. Choice of the number of poles and of

the arrangements for staying them must be left to the judgment of the individual worker, who, however, must bear in mind that for a given distance of working, the *total* height of a free aerial slung between poles fixed in the ground need not be so great as that of one raised on poles at the top of a house; this is because the wire down the side of a house

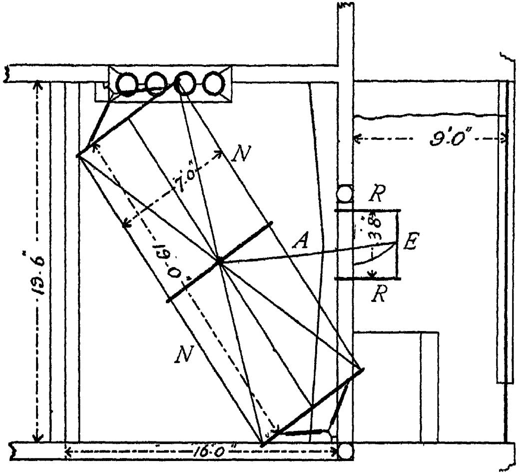


FIG. 8.—Plan showing Main Dimensions of Wireless Telegraph Station at Hampstead.

is seldom so effective as one free in space. If the aerials can be erected on hills there is a distinct gain, especially if the land lying between them is full of houses, etc.

An Example of an Installation.—Proceeding to a description of the author's experimental installation

for working between Hampstead Heath and Tufnell Park, a summary of the facts and figures of the case will be followed by a more detailed description of the arrangements for staying, insulating, raising, and lowering the network. Figs. 8 and 9 give a plan and an elevation of the house at Hampstead, showing the main dimensions of the network and aerial.

Distance : $1\frac{3}{4}$ miles.

Nature of intervening ground : No hills, but covered with houses, railway and telegraph lines, trees, etc.

Type of aerial.—Rectangular network suspended almost horizontally, with aerial wire attached at centre and brought down front of house.

Dimensions of network : 19 ft. by 7 ft.

Average height of aerial above roof : 13 ft. 6 ins.

Average height of aerial above ground : 50 ft. 8 ins.

Nature of lower-capacity area : Iron railings let into dry concrete.

Average height of top of railings above ground : 5 ft. 8 ins.

Effective distance between upper and lower capacity-areas : About 48 ft.

General remarks :— Immediate surroundings of sending station were slightly rising ground with a row of willow trees in the direction of receiving station and houses in other directions. An iron rain-water pipe ran up at a distance of about a yard from the aerial wire, and a narrow strip of lead lay between the roof-edge and the parapet. Immediate surroundings of receiving station at Tufnell Park were houses with ground descending in the direction of Hampstead. The weather was hot and dry during most of the tests. (NOTE.—The best weather

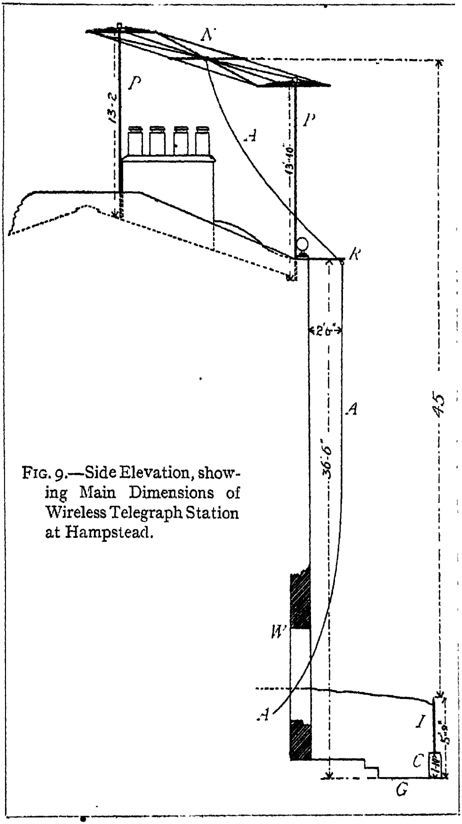


FIG. 9.—Side Elevation, showing Main Dimensions of Wireless Telegraph Station at Hampstead.

and time for signalling is damp or foggy weather at night, though dry weather makes good insulation easier.) For information as to size of spark coil, etc., see below.

Detailed Description of Installation.—The network N, Figs. 8 and 9, was made in the following manner: Two pieces of wooden rod, about $\frac{3}{4}$ in. diameter, were cut to a length of 7 ft. 1 in., and in the centre of each and about $\frac{1}{2}$ in. from each end a notch was cut so as to completely encircle the rod and give a good seat for No. 12 or No. 14 copper wire without weakening the rod. Both rods

FIG. 10.—First Stage in the Construction of Aerial Network.

were then painted. When the paint was dry, three carefully stretched and straightened pieces of No. 12 copper wire, 19 ft. 7 ins. in length, were bent round the grooves on one wooden rod, the returned ends being twisted round the wires.

The free ends were similarly fastened to corresponding grooves on the second rod so that the wires lay parallel to each other, when the two rods were stretched apart. At this stage the appearance of the network was as shown in Fig. 10.

The two wooden rods were then stretched apart by ropes fastened to any convenient and firm fixture,

and three pieces of wire were laid across at right angles to the first three pieces—one being placed near each end and one in the centre. These wires were twisted two or three times round the original three at the ends, and once at the crossing points.

Two diagonals were then added, and these, like the cross-pieces, were twisted at their ends and centres round the previously placed wires. Fig 11 (*A*) shows by dotted lines the completion of the network.* All twists and crossings were soldered, and finally a short piece of No. 12 copper was twined into the knot of wire at the centre of the network, the whole junction being bound round with thin copper wire (preferably tinned) and soldered into a solid mass. The short piece of wire finally added, was provided for the convenience of attaching the aerial wire.

A length of small bamboo (a lath would serve the purpose equally well) was placed across the network and along the wire B C, which was tied to it at three or four points, the bamboo and the ties being well painted to preserve them and to prevent the latter from slipping. The object of the piece of bamboo is to keep the central wire straight, as otherwise it would buckle. At 3 or 4 ins. from each end of the two wooden rods, W W, Fig. 11, a circular groove was cut; copper wire was twisted tightly round it and threaded through a diametrical hole, drilled at ¾ in. from the end of a ⅝-in. rod of ebonite, E, Fig. 11 (*B*); each twist was soldered and painted.

The ebonite rods were 10 ins. or 12 ins. in length; 12 ins. over-all would probably afford ample

* The additional wires visible in some of the photographs are superfluous.

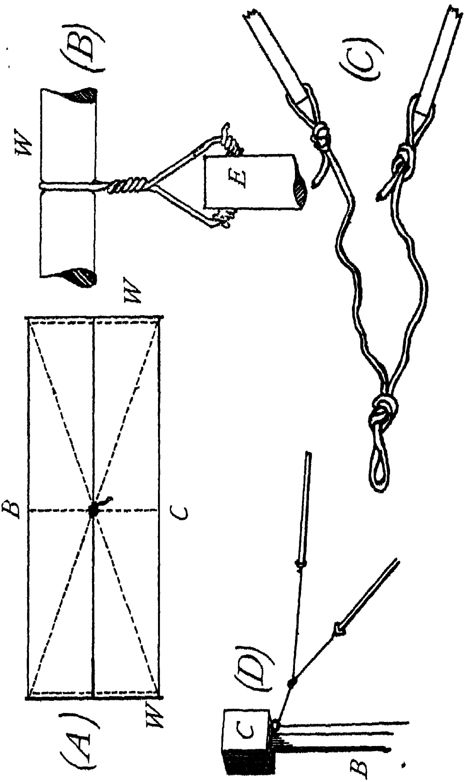


FIG. 11.—*Details of Construction and Suspension of Aerial Network.*

insulation. The other ends of the ebonite rods were similarly drilled, the edges of the holes being slightly countersunk to avoid chafing. One end of a short length of stout cord was threaded through each of the ebonite rods at one end of the network, and securely tied; the cord was then looped in the middle the result being as shown in (*C*), Fig. 11. A similar attachment was made at the other end of the network.

FIG. 12. Fastening of Pole.

The arrangements for running the network up and down were as follows :—

The tops of the bamboo poles from which the network was hung were each provided with a cubical cap of wood, C, which was drilled to about half its depth with a centre-bit, so that the end of the bamboo B could be forced into the hole. The block and the

end of the pole were thoroughly heated, and a little melted pitch was poured into the hole and the bamboo forced in as far as it would go. When the superfluous pitch had hardened, it was chipped off and the pole and block were painted. A stout brass eye was screwed to the under side of the block as shown in the figure, and when a rope had been threaded through the eye the pole was fastened in its place.

Both poles being secure, each of the ropes was attached to one of the loops of cord on the aerial, which was raised into position by pulling the ends of the ropes which hung down from the eyes.

Somewhere near the bottom of each pole was placed a staple-hook, round which the rope could be twisted; (*D*), Fig. 11, and the photographs will make the foregoing account clear.

The methods of fastening and staying the poles are clearly indicated in the accompanying photographs. Fig. 12 shows how one of the bamboo poles, a little over 13 ft. in height, was held behind an iron bar let into the angle of the chimney and wall. Holes were made in the concrete with hammer and chisel, and the bar sunk in Portland cement, which completely filled the holes.

The small flat space at the bottom of this angle is lead-covered, and as it was thought inadvisable to allow the bottom of the pole to rest on this, a bed of cement was made to distribute the pressure over the lead.

Higher up on the slope of the chimney-stack, a pair of very large screw-eyes was bedded in holes filled with cement, and the pole was secured by ropes passing round it and through these eyes, as shown.

With this double fastening, the pole required only one guy-rope, for which a staple hook was cemented into the low concrete wall to the left of the chimney. No guy-ropes could be brought to bear on the other pole in such a way as to counteract the pull of the stretched network. The way in which this difficulty

FIG. 13.—Method of Staying Pole by Struts and Tension Cords.

was surmounted is seen in the photographs, Figs. 13 and 14.

Two small bamboos were very securely fastened by ropes as high up the pole as was convenient. Each bamboo was then passed under a large cemented staple on a wall or parapet, and a deep notch was cut in the concrete behind the staple so

that the end of the bamboo could butt against the back of the notch; a channel was provided in order that no water should collect in the notch and rot the bamboo, or freeze and split the concrete.

Two ropes were then fastened to the pole and attached at considerable tension to staple-hooks,

FIG. 14.—Aerial Framework. Method of Bedding the Struts.

cemented into the wall or parapet behind the notch. Fig. 14 shows bamboo, notch, channel, staple, staple-hook, and rope.

Thus, the drag of the network was taken up by pressure along the bamboos, and any tendency of the latter to come out from the staples in high winds, when the aerial was down, was opposed by the ropes.

The lower end of the pole shown in Fig. 13 was bedded in cement, which was provided with a channel, as shown in the photograph, Fig. 14. The pole was secured by ropes to the parapet ball, shown in the photograph.

A foot length of ¼-in. ebonite rod was fastened to each corner of the network, and a piece of string attached to the other end of the rod was secured to one or other of the staple-hooks; this prevented all swinging and wobbling of the network.

The aerial A, Figs. 8 and 9, which was composed of two strands of thick copper wire, was attached to the short lug of wire at the centre of the network by means of a very tightly fastened barrel-connector; it then passed down in a sloping direction to a piece of rubber tube tied across the ends of two wooden rods R R, projecting well out from the parapet, and thence down the front of the house and in at a window W on the ground floor. Rubber was not found satisfactory, but a 2-ft. length of ebonite rod hung by rope between projecting wooden rods, would meet all requirements. In the case in question, the wooden rods were 3 ft. 8 ins. apart, and were secured to the parapet by tying them to staple-hooks in such a manner as to hold the tube about 18 ins. away from the parapet; but this distance might, with advantage, be increased to a yard or more.

In Figs. 8 and 9, P P are the poles, E is the rubber tube or ebonite rod, I the railing used for earth connection, W the window of the apparatus room, G the ground level, and C the railing wall. The reader must use his own ingenuity in designing his aerial networks, as each individual case calls for its

own treatment; nevertheless, he may find useful hints in this account of the arrangement made use of in one particular example.

Taking one instance of limitations, the author would have preferred a square network of the same

Fig. 15.—Telephoto View of Top of House and Aerial Network. Picture taken from Hampstead Heath.

area as the one he actually used, running parallel to the roof-ridge and giving a greater effective height above the roof. This was impossible, because there was nothing convenient for attachment at the

chimneyless side of the house. The slope of the network as used in this case does not affect the results.

Again, the poles might be made higher, the only limits in this direction being the difficulty of erection, danger of strain on fixings, etc., from windage, and last, but not least, the length of the experimenter's pocket.

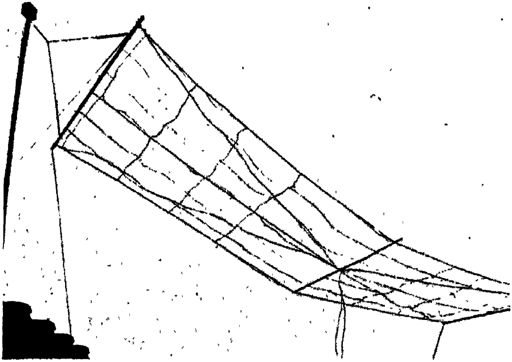


FIG. 16.—View of Aerial Network. Picture taken from Roof of Building.

Figs. 15, 16, and 17 are reproduced from photographs of the aerial.

In some cases, the plan of planting the poles in small tubs full of cement may be found advantageous, but extra precautions must be taken against shifting, blowing over, etc.

If four poles are used the network may be slung

up by ropes passing from each pole to a corner, and in this case the small guys of string with their ebonite insulators will not be required.

The area of the network must depend very largely on the power of the spark coil which is available, for this delivers a certain amount of energy at each break of contact, and if the area be too great

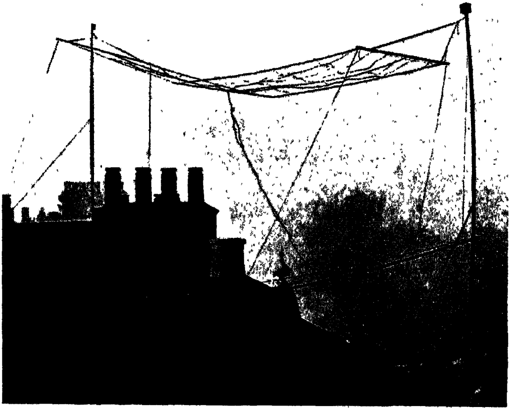


FIG 17.—Another View of Aerial Network.

such energy will be insufficient to charge the network to the requisite potential. If, on the other hand, the area be too small, energy will be wasted. The reason for this is that the spark must not exceed a certain length for good working, and if the gap is adjusted for the best results while the coil is capable of charging the aerial to a far higher potential than

is required to discharge across that length of gap, the spark will pass before the aerial is fully charged, and the remaining energy supplied by the secondary will pass quietly across without producing oscillations. Moreover, this superfluous energy creates so hot a spark that, if the discharges are passing in rapid succession, they flow comparatively quietly through the column of hot air in the gap and maintain an arc-like passage in which they are wasted in heat. This prevents the sudden snap necessary for the proper production of oscillatory currents.

Networks are easily made and altered, and the reader must judge as far as possible from circumstances what the dimensions should be, and make modifications according to the results obtained by rough experiment.

It is well to bear in mind that the energy available should be a little more than is necessary to produce the required spark-length, as there is usually some inequality in successive discharges from a coil. This causes a tiresome tendency to "miss fire," which is very annoying in practical working. Coils fitted with an ordinary platinum break are specially apt to give this trouble.

In the last few paragraphs, the author has assumed that the experimenter possesses, or can afford, a coil of a certain power; but, of course, if his pocket will allow of it, he may construct his aerial and then choose his coil and other apparatus to suit.

For signalling about a house or over a few hundred yards, networks of small area may be hung up in almost any way, horizontally or by their edges or corners, and need only be well insulated and secure. The lower areas may be made up of sheets of

galvanised netting laid on the floor or ground, and supplied with copper feeders at two or three points.

Returning now to the sample installation: the aerial wire passed in through an open window and was carefully held away from contact with any woodwork, etc., by string attached to the blind fastenings. In damp weather "catapult-rubber" would be preferable to string. In cases where it is not convenient to have the window open, or where a special hut is used, the wire must be brought into the building through a thick tube of ebonite projecting a considerable distance from the wall or other surroundings on both sides. The tube should be placed at such an angle that rain runs towards its outer end, and not down its interior towards the apparatus room. A small rain-hood may be placed over the outer projection if the rain beats inward.

In the case in question, the aerial was connected directly to one discharge rod of the coil, the other going to the lower capacity-area or earth without any particular precautions as to insulation.

Both discharge rods were, of course, fitted with spark-balls, and the gap varied from about $\frac{3}{8}$ in. to $\frac{1}{2}$ in.

Some experimenters, however, may prefer a separate spark-gap, and it is very useful to provide a screw adjustment for one of the balls. Balls or round-ended rods must be used invariably, and the insulation between the two balls and between the aerial-connected ball and the earth must be good.

In the case in question, the earth connection was made at two or three points on a row of iron railings and a gate. These only partially realised the ideal of an insulated lower capacity-area, for they were

raised on a fairly high and dry low concrete wall. The railings used at the receiving station were even less well insulated.

An Apps coil was used and gave a very fat and heavy 4- or 5-in. discharge when disconnected from the aerial. Mercury- and hammer-breaks were both tried, and experiments were made at various supply voltages from accumulators.

The best results were obtained with a mercury-break at a high speed, and a set of accumulators giving 24 volts, but a still higher voltage would have been advantageous. The receiver was a roughly made Lodge-Muirhead wheel with a simple potentiometer quickly put together. Further details are given on another page.

There seemed to be plenty of sensitiveness to spare, as experiments showed that reception could be carried on under conditions which were deliberately made unfavourable.

In order to give a consecutive account of the Hampstead installation, the author has made some digression from the subject of aerials, but will now proceed in order to the consideration of the apparatus necessary for charging them.

Apparatus for Charging Aerials.

Induction Coils.—Setting aside the special alternate current transformers now used for large installations and long-distance working, the induction coil is unquestionably the best producer of the high-voltage impulses necessary for charging the oscillator or aerial.

At the outset the reader must clearly understand, once and for all, that if the spark length of a coil be above a certain value, the most important

requirement is not *necessarily* a very high voltage, but *essentially* a sufficient delivery of energy with each discharge to raise the aerial to the desired potential or voltage with regard to the earth.

Amateurs constantly ask what length of spark will be required for signalling to a certain specified distance. Apart from the absurdity of attempting to answer a question which involves so variable a range of circumstances, the spark length is only a rough criterion of the operation which may be expected from a coil used for this purpose. The author has known an 8-in. spark coil which was much inferior to one giving a 6-in. discharge, because, though the voltage was of course higher, the quantity of electricity conveyed across the gap by the 8-in. coil was less than that delivered by the 6-in. coil, which gave a heavy "fat" or "bushy" discharge.

It has been explained already that a coil may be too large for a given aerial, and this particularly applies to small laboratory oscillators.

The best results are obtained from Lodge, Hertz, and other *laboratory* oscillators by using small coils giving comparatively feeble discharges, and this fact seems to be but little recognised by beginners. The author has obtained good signals all over a house with a ½-in. spark coil and a Hertz oscillator, the latter refusing to do the same work when supplied by a 4-in. spark coil. The reason was that, however finely the break of the large coil was adjusted, the discharge was too heavy and produced the arcing effect described on page 59.

Experimenters who have desired large and expensive coils for Hertzian wave work may be pleased

to know that good results can be obtained from room to room with coils giving sparks only $\frac{1}{8}$ in. or $\frac{1}{4}$ in. in length.

The type of coil used is not important with laboratory oscillators, but needs careful attention when large aerials are used, especially if there is an earth connection, either good or bad.

There are certain coils on the second-hand market which have secondaries made up in two sections wound in opposite directions, and carefully insulated from each other by a disc of ebonite. The sections are slipped over the primary coil without any intervening insulation, and they are connected in series by a wire which joins their innermost layers to each other and passes over the surface of the primary coil and under the edge of the insulating disc. The difference of potential between the outermost layers of the two sections is thus double that which exists between the outermost layer of either section and the core.

The result of this arrangement is that if one secondary terminal be connected to an aerial and the other to earth, that section of the secondary which is connected to earth is short-circuited whenever the core or the primary coil, or anything in connection with them, is earthed. Thus, not only does the coil work at half its power, but if the earthing of the primary is imperfect, everything in connection with it is alive and very unpleasant shocks result from touching contact-breaker, key, commutator, lead wires, or accumulators. The passage of the sparks between the primary coil and the connecting wire between the two sections also chars their cotton or silk coverings.

The difficulty might be surmounted by raising coil, accumulators, key, and break (if separate) upon an insulating platform, the key being one of very high insulation; but all adjustments would have to be made with the coil not working, and even then the capacity of the accumulators, etc., would probably be sufficient to draw off some of the discharge and cause a little sparking between primary and secondary.

Mr. H. W. Cox, of Rosebery Avenue, who was the maker of these coils, does not turn out any which are not fitted with ebonite tubes between primary and secondary. These coils, as made at the present time, are therefore as suitable for radiotelegraphy as any on the market. Before investing in a second-hand Cox coil, the reader is recommended therefore to find out whether it is one of the old type or one properly insulated in this manner. Any spark coil for radiotelegraphy should be well insulated everywhere, especially between primary and secondary. The primary resistance should be fairly low, and if the coil is to be moved about, used on board a vessel, or subjected to atmospheric variations, it should be well built in all parts, and securely fixed in a strong box with a removable well-fitting lid. Some makers build the coils into wooden cases for rough field-work with X-rays or radiotelegraphy. Experimenters who wish to build their own coils must refer to some separate work on the subject. (See No. 11 of *The Model Engineer* Series—"Induction Coils for Amateurs.")

Interrupters.—The Platinum Break.—Coils are usually fitted with platinum contact-breakers, and of these there are various types. With small coils

for charging laboratory oscillators, the simple hammer-break usually fitted is ideal; but when aerials of larger capacity are used, heavy currents must be made and broken with great rapidity and regularity, and any of the older forms of platinum break become expensive and tiresome.

The heat of the current causes the platinum contacts to stick together and burn; particles are torn off and carried across from one to the other, making projections and corresponding hollows which sometimes become locked or fused together, and, with this pitting and roughening, the contact-resistance rises.

Heavy currents also cause small particles to be torn off and dropped, and there is further waste of platinum in the process of filing periodically required to remove roughnesses which get too troublesome. The renewal of the platinums for a large coil costs 10s. or 20s., and the price is rising.

Setting aside the simple type of hammer-break supplied with small coils, there are other fairly common designs to be met with on modern coils—namely, the Apps and the Vril. The latter, which is admirably adapted for X-ray work, is dealt with in the author's handbook on "Radiography"; it is too slow for good wireless signalling, even if provided with the extra light hammer described in the handbook.

Probably the Apps break would prove the least troublesome among the older types, but Mr. Cox has recently placed on the market a platinum interrupter of entirely novel design and great superiority. Its action is clearly shown in Fig. 18.

The ebonite base is fixed against the end of the

coil, so that when the core of the latter is energised it can attract the light iron armature A through the base. The pull of the spring Y, which holds A against the adjustable back-stop N, can be varied by means of the screw-head P. The ebonite milled

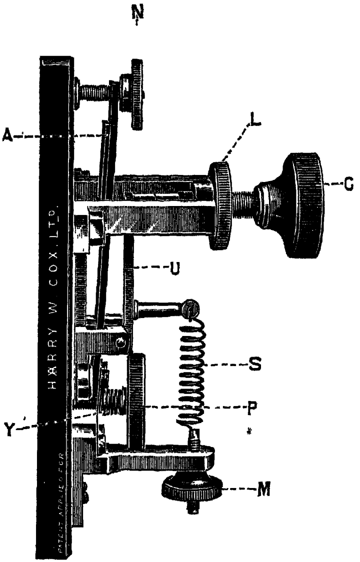


Fig. 18.—New Platinum Interrupter, by Harry W. Cox, Ltd.

head C carries the back contact-piece of the break, and is locked by the milled nut L. The front contact-piece is attached to the U-shaped piece marked U, and is held against the back platinum by the spring S.

When the current is turned on, A is pulled to the left, and during the whole of its travel the platinums remain in firm contact. Eventually it gives a smart blow to the left-hand arm of the U piece, and knocks the platinums apart very suddenly, and for a very short distance and time. A flies back when the field dies away, and the platinums immediately touch again, remaining in contact during the greater part of the backward and forward travel of A.

This interrupter has considerable range of adjustment, is very rapid in action, gives a long make, and a sudden and complete break, does not stick, and greatly reduces the loss of platinum by burning. It can be used in parallel with a suitable non-inductive resistance on 100-volt lighting mains.

Mercury Interrupters.—Mercury interrupters are, broadly speaking, of two classes—one in which some sort of dipper is immersed in mercury and withdrawn, either by a rotatory or by a reciprocating motion; and another, in which a jet of mercury, that normally forms a connecting bridge between two conductors, is alternately broken by a set of revolving teeth or projections and allowed to reform.

It is not within the province of this book to give a detailed description of the various interrupters in use at the present time, but the author proposes to emphasise the main advantages of the different types and to show the reader what must be his main considerations in making a choice. Among the dipper forms of break are the following:

(1) A reciprocating copper dipper attached to an armature provided with a spring and kept in motion, either by the variations of magnetism in

the core of the induction coil itself, or by means of a separate magnet, battery, and contact. The latter variety could be made by attaching the dipper to the armature of a large electric bell. The rapidity of action of these can be varied within certain limits by adjusting the inertia and control of the vibrating part.

Interrupters of this type are cheap and easily made, and if a great range of rapidity were required, one or two of different sizes could be used. It is not easy, however, to construct them so that they start vibrating instantly when the key is depressed and leave off directly it is released.

One great advantage of those with separate magnets is that they can be designed in such a way as to keep the circuit open when they are idle, by holding the dipper up, contact being made when the armature is pulled *down* by the magnet. By this means the signalling is accomplished with a key which only makes and breaks the small current used by the magnet. Otherwise, the interrupter must be kept in continual vibration and the signals made by means of a key carrying the far larger current taken by the induction coil.

(2) The Lodge-Muirhead buzzer break is, perhaps, superior to any other for the purpose of wireless signalling. It is prompt and sharp in action, rapid and regular in its motion, and fairly simple in construction—simpler, at any rate, than the "turbine" jet interrupters. A full description is to be found in the section on Wireless Telegraphy, written by the author for "Outlines of Electrical Engineering" (H. H. Simmons; Cassell & Co.). Like the interrupters described in (1), the Lodge-Muirhead buzzer

break holds the circuit open when at rest, and the signals are made by a key which carries no heavier current than that required to actuate a Morse sounder.

(3) A very useful form of dipper-break is one in which the motion is reciprocatory, but is supplied by a crank worked by a rapidly rotating motor. The dipper is usually attached to a steel rod running in a guide like a piston-rod; a copper brush presses on the rod making good, contact with it. Sometimes two dippers are connected to cranks 180 degs. apart, so that contact is made twice in a revolution. This halves the speed at which the motor must run, diminishes the vibration of the apparatus, and ensures the maximum possible time of contact, together with the occurrence of the break at the moment when the dipper is moving most rapidly. With this type of interrupter the whole of the current must be carried by the signalling key, but the action is very regular and the speed can be adjusted beautifully by means of a rheostat in series with the motor.

(4) The Mackenzie-Davidson interrupter consists of a rapidly rotating motor-driven shaft with a quadrant or scythe-shaped blade of copper fixed at its end. The shaft is canted at such an angle that as it rotates the disc dips into and out of some mercury in a vessel and never emerges above the surface of a layer of paraffin or methylated spirit which covers the mercury. The speed can be regulated as easily as that of No. 3.

General Remarks about Dipper Breaks.—The time of contact can be regulated in all the dipper breaks by raising or lowering the level of the mercury,

which in all cases is covered with paraffin oil or methylated spirits to such a depth that the dipper never emerges.

The action of these liquids is to quench the arc which tends to form at the moment of break, and thus render the interruption suitably sharp and sudden. All dipper breaks beat and churn the mercury into minute globules, which, in time, form a thick grey mud with the covering liquid. This mud, if allowed to accumulate too much in the break, is worse than useless, but contains a great deal of mercury and should not on any account be thrown away. It is the difficulty of regaining this mercury in a simple form which has led the author to use methylated spirit as a covering liquid rather than paraffin oil. All that is then necessary is to put the mud into an evaporating dish or enamelled iron saucer and set fire to it. In a few minutes the whole of the spirit will have burned out and the globules will have run together. When the mass of mercury is cool, it can be skimmed or strained through a cloth and is then ready to be returned to the break.

The reader must observe caution in the use of methylated spirit, however, as it is liable to get hot if the containing vessel be small, and this leads to a rapid evolution of dangerous inflammable alcohol vapour which is easily ignited by a spark at the brushes. Plenty of mercury and plenty of spirit should be used, and the containing vessel should be of iron and open and so arranged that it can easily be covered over for air exclusion if it catch fire. The apparatus should also remain under the immediate observation of the operator while at

work. Spirit should not be used where the container is closely shut in.

Mercury Jet Interrupters.—These interrupters are sometimes known as "turbine" breaks. Broadly speaking, they consist of a metallic nozzle out of which is forced a thin continuous jet of mercury that impinges on a metallic contact pin or plate, or falls into the mercury container provided, thus establishing connection between the nozzle and the plate or container. A revolving crown carries large saw-tooth-like projections of copper on its circumference so that they alternately intercept the stream of mercury and allow it to re-establish itself. In some cases the nozzle revolves and the teeth stand still, and there are various ways of pumping the mercury through the nozzle at the requisite pressure.

These interrupters are expensive to buy and more troublesome to make than dipper breaks. They are, however, held in very high estimation by those who have used them.

Choice of Interrupter.—On the whole, the amateur is advised to use (*a*) a motor-driven break of the Mackenzie-Davidson type; (*b*) a motor-driven crank-break with one, or, better still, two reciprocating dippers, each crank-driven.

The experimenter must not forget that any external interrupter must be so connected as to occupy precisely the same position as the platinum break; that is, in series with the primary and shunted by the condenser. If no terminals are provided for making this connection, wires must be screwed or otherwise properly connected with the contact pillars of the platinum break.

Wehnelt Interrupters.—The author has had no experience of the use of these for radiotelegraphy

but is of the opinion that they would prove unsuitable in many respects, and certainly inferior to good mercury interrupters.

SOURCES OF SUPPLY.

Supply Mains.—Mention has already been made of a platinum interrupter, which can be used on ordinary continuous-current mains; these are also suitable for working a Wehnelt or high-speed mercury break. For charging very large aerials alternating-current mains may be used, especially if the induction coil be specially designed for this purpose. Each half-wave of the current charges the aerial in the opposite direction to that preceding it, and the discharge should occur as nearly as possible at the moment when the potential is at a maximum. As very few readers will be working with installations to which it would be advisable to apply this method of charging the aerial, the author will not go into details as to the best wave-form and frequency of the alternator and the design and management of the coil.

Mr. Cox now makes a break of the Wehnelt type which works in conjunction with a modified aluminium cell on alternating current mains. The cell checks one half of the wave, and the other half is interrupted in the electrolytic break. Splendid sparks are produced by this arrangement, which seems to be very satisfactory, but has not been tested by the author.

Primary Batteries.—These are very suitable for small oscillators charged by coils giving sparks up to 1 in. in length; but as larger and larger coils are needed, the batteries become unwieldy and

troublesome to keep in order, and cause an intolerable mess and waste of time. The cells may be of the Grove, Bunsen, or bichromate types, but, taking all things, including cost, into account, probably the last-named is most suitable. Here, again, the reader must refer to other books for details of various primary batteries, and must exercise his own judgment in making a choice of the type of cell which he will employ. (See No. 19 of *The Model Engineer* Series, "Electric Batteries.")

Accumulators.—The best source of supply for induction coils is undoubtedly a storage battery, for the voltage of a single accumulator cell is higher than that of any known practical primary cell. The internal resistance is very low, and for a given bulk the capacity in ampere-hours is far greater than that of any primary cell. The capital outlay is greater for an accumulator than for a primary battery of the same power; but good accumulators can be obtained at a reasonable price, and would probably work out cheaper than primary cells in the end, even for small powers, especially if the owner were able to charge them from his own dynamo, or even from lighting mains with a lamp resistance inserted. Now that motor-cars fitted with ignition coils travel over the whole country, there should not be much difficulty in getting portable accumulators charged anywhere.

The experimenter must use his own judgment in the choice of accumulators, but is advised to use those of the portable type, unless the power required is so great as to necessitate stationary cells.

The voltage of the battery, whether primary or secondary, is strictly limited by the size and type

of the coil and by the design of the interrupter. Large coils, with platinum breaks, usually work at about 12 volts, but with motor-driven mercury interrupters the voltage may be as much as 50 or 100. This does not mean that the difference is wasted in the interrupter; the explanation is as follows:—

A definite and appreciable amount of time is required for the building up of the magnetic field in the core of the coil, because during the whole time of its formation it is inducing in the primary coil electro-motive forces which oppose the applied E.M.F. (see page 10), and retard the growth of the primary current. It is obvious, therefore, that by increasing the applied electro-motive force the period of growth will be shortened, and contact will not need to be maintained so long as before to obtain the required saturation of the core.

Putting the case in another way, the higher the speed at which the interrupter is run, the higher must be the applied voltage necessary to saturate the core to the required degree in the short time during which it is applied. Thus, if a 10-in. spark coil run from a 12-volt set of accumulators with a mercury interrupter were just able to give the full 10-in. spark with the motor running at 20 revolutions per second, an increase of speed would lessen the spark length until—at 60 revolutions per second—it might be reduced to 2 or 3 ins. If, now, the speed were kept up to 60, and the voltage gradually raised, the spark length would rise to its full value; now, however, the number of sparks produced per second would be three times what it was before.

For radiotelegraphy we require a very rapid torrent of sparks, and for this reason we must supply

a voltage sufficient to enable us to run the interrupter at a high speed. Results may be obtained at low speeds, but the difficulties of working are increased, and the experimenter is advised to run at as high a speed as possible (within reasonable limits). Thus the rapidity of the spark will depend partly upon the amount which can be spent on accumulators and partly upon the ease with which they can be charged.

For working over comparatively short distances coils of 2-in. or 3-in. spark length may be used, and considerable rapidity can be attained with these at comparatively low voltages. As to the ampere-hour capacity required, this will depend entirely upon the current taken by the coil, and must be left to the decision of the individual concerned, who will know what current his coil takes, how long he intends to run it at a stretch, what his charging facilities are, and how much he can afford to spend on his battery.

The voltage used with the mercury break in the installation previously described was not sufficient to give the rapidity of sparking which would have yielded the best results.

For further information on the construction and maintenance of storage cells see No. 1 of *The Model Engineer* Series, "Small Accumulators."

Wimshurst and other Influence Machines.—These cannot be recommended for radiotelegraphy, as their discharge is neither sudden nor regular; the rate of sparking with a given aerial depends upon the rapidity with which it can be charged by the machine used.

The induction coil gives a momentary violent rush of electricity, whereby the aerial is charged so rapidly

that there is little time for leakage before the discharge occurs.

The influence machine, however, charges gradually, and during the gentle rise of the aerial to the required potential there is plenty of time for very serious leakage, if this method is adopted: the experimenter must accordingly take special precautions for very thorough insulation at all points. They will answer the purpose for ringing bells, etc., in a house; but special care must be taken to polish the spark-balls, as the discharge from these machines has a great tendency to brush and spit off wherever there is a roughness or point. There is no method of breaking up the spark into signals except by short circuiting the machine when the discharge is not required, or using an insulating sheet, which lies between the gap-balls and is moved out by the depression of a signalling key. Such devices are clumsy, and likely to cause much trouble.

Signalling Keys.—Distinction has been made already between interrupters which are so designed as to necessitate the making and breaking of the whole current by the signalling key and those which require a key only carrying the energy needed to keep the interrupter armature vibrating. (See page 68.)

Any simple press-key with platinum contacts will answer the purpose in the latter case, but where the key makes and breaks the main current, the contacts must be heavy, especially if low voltages are used: for even if the platinums do not get burnt, they may introduce objectionable contact resistance.

The author made a cheap and useful signalling

key, consisting of a pair of mercury cups placed side by side in a baseboard; a two-prong copper dipper was attached to a broad strip of springy brass, and arranged so that it bridged the cups when depressed. The tips of the prongs were amalgamated, as were the copper wires leading from the cups to the terminals of the key. A round-headed screw passed loosely through a hole in the brass strip, and was screwed into the baseboard; the strip pressed up against the under side of the screw-head, which thus formed an upper stop. An ebonite knob was fastened to the brass strip to prevent unpleasant shocks from earth-leakages. (See Fig. 19.)

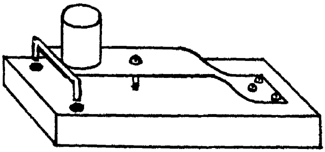


FIG. 19.—Simple Signalling Key for Heavy Currents.

Further Details of the Transmitting Apparatus.—Various useful additions to the transmitting arrangements may be made; in some cases, for instance, a switch is useful, and a fuse is almost always a valuable safeguard to the apparatus, especially where accumulators or lighting mains are used.

A variable resistance of suitable design is also useful in certain cases, while an amperemeter, and even a voltmeter, though not essential, are luxuries which greatly add to the interest and value of experiments.

The amateur is not advised to attempt closed-circuit discharge systems, either directly coupled

to the aerial or inductively coupled by means of an oscillation transformer.

Some of the best work of the present time is done by aerials receiving their charge directly from the coil. In the diagram of connections shown in Fig. 20 N N are the upper and lower capacity-areas; G is the spark-gap; T_1 and T_2 are the primary and

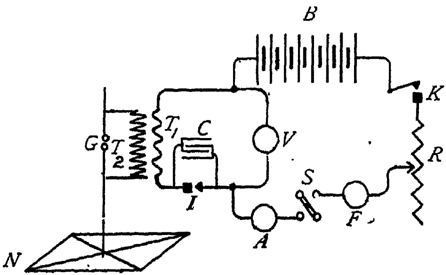


FIG. 20.—Connections for a Convenient Sending Circuit.

secondary of the spark-coil; I is the interrupter, and C its condenser-shunt; B is the battery, K the signalling key, R the variable resistance, F the fuse, and S the switch. A and V are the amperemeter and voltmeter.

CHAPTER IV.

RECEIVING APPARATUS.

ARRANGEMENTS FOR CHANGING OVER FROM TRANSMISSION TO RECEPTION.

WHEN dealing with the receiving apparatus, we must remember that up to a certain point it is identical with that used for transmission; in fact, if it be desired to transmit as well as to receive at one station, the same network, aerial wire, and lower capacity-area are used, and all that is necessary is to connect the receiving apparatus between the two spark-balls so that any oscillations induced in the aerial by incoming waves pass, or tend to pass, through the receiver to the earth or lower area. A large number of the readers of this book will probably be content with a transmitting and a receiving station, for, if each is to be capable of performing both functions, all labour and expense except that which is demanded for making the aerials themselves, must be exactly doubled.

For those who require it, however, Fig. 21 shows the connections for a simple switching device, which changes over from transmission to reception. The diagram shows its application to Lodge-Muirhead apparatus without an oscillation transformer, and

the reader must devise any modifications which are necessary for other apparatus.

The meaning of the various parts indicated in the diagram will be better understood after reading the account of the Lodge-Muirhead receiver.

In Fig. 21, A is the aerial, E the lower capacity-area, G the spark-gap, and S C the induction coil secondary. B is a bar of ebonite 2 or 3 ins. long, at each end of which a tapered brass plug is fastened; the plugs are connected above and below the spark-

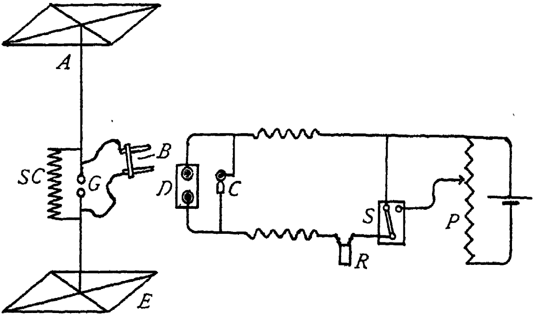


FIG. 21.—Arrangements for Connecting Aerial for Transmission or Reception.

gap as shown in the diagram. D is a small baseboard, into which a pair of brass sockets are sunk at such a distance apart that the pair of plugs can be thrust into them so as to make thoroughly good contact. Each of the sockets is connected to one terminal of the coherer C, so that on inserting the plugs, C is connected between the wires leading to the upper and lower capacity-areas.

If the reader does not wish to take the trouble

of fitting the plugs to the sockets, copper plugs and mercury cups may be substituted.

The change-over switch S is shown turned to the left for sending, in which position it short-circuits the coherer C and the moving-coil indicator R, and disconnects the supply from the potentiometer P. On changing over the switch, the short-circuit is removed, the circuit P C R S is re-established, and if the plugs B are in place all is ready for receiving.*

Comparison of Receivers.

Among the great advantages which the Lodge-Muirhead apparatus possesses over the filings-tube type are the following :—

The number of essential electrical parts requiring adjustment is less, for whereas the filings-tube receiver requires coherer, cell, relay, battery, tapper, and indicator (either sounder or recorder), the Lodge-Muirhead apparatus needs only coherer, cell, potentiometer, and indicator. The adjustment is extremely simple, and can be accomplished in less than half a minute, whereas to obtain the *best* working conditions with filings-tubes, considerable adjustment of the relay and often of the tapper is generally necessary; difficulty is sometimes experienced in getting the motion of the tapper to take place in such a way that it does not interfere with that of the Morse recorder or sounder.

Again, the Lodge-Muirhead wheel coherer is absolutely regular and certain in action, whereas filings coherers are not always reliable in action.

The wheel coherer is perhaps more difficult to construct than a simple filings tube, though, if the

* For protection against accident a second pair of sockets may be used for connecting the aerial to the coil secondary.

latter be required for equally fine and sensitive work, there is no great difference between the two, since several attempts must often be made before a successful filings coherer is produced. The moving-coil indicator in its simplest form can be made with no greater difficulty than a really sensitive relay, and a simple slide-wire potentiometer presents less difficulty than the remaining necessaries for use with the filings-tube.

On the other hand, the Lodge-Muirhead coherer requires clockwork to keep it in rotation.

Lodge-Muirhead Apparatus.

The reader must not be alarmed at the somewhat complicated appearance of the apparatus shown in the drawings and photographs which illustrate this description of a receiver of the Lodge-Muirhead type. Although there is much fine work, requiring care and nicety of fitting, there is nothing which presents great difficulty, and patience is of more importance than great skill.

With the exception of the steel cylinder, which is supported centrally in the moving coil of the indicator, and the brass rod, which forms the spindle of the potentiometer contact-arm, the whole of the turning was done with a hand-rest lathe which had a loose bearing and an untrue self-centreing chuck.

Moreover, the apparatus here described was made with a view to the greatest possible convenience, range, and rapidity of adjustment, so that experiments on its sensitiveness and certainty of action under various conditions could be easily carried out; an efficient signalling installation might be constructed on far simpler lines, which will be suggested in the

course of an exact description of the receiver made by the author.

Before commencing this description, a brief outline of the construction and action of the apparatus as a whole will be given.

The coherer consists of a small steel wheel with a sharp edge which grazes the rounded top of a column of mercury.

The wheel and mercury are covered with a slight film of oil, which is sufficient to insulate them from each other if the potential difference between them is not above a certain small value. A potentiometer, or, rather, potential-divider, gives the necessary adjustment of the voltage between wheel and mercury, and the film is not broken down until this steady voltage is aided by the extra impulse of the wave-induced oscillations in the aerial.

The breakdown, when it occurs, is fairly complete, and a small current flows from the potential divider through the wheel and mercury and also through some piece of apparatus for indicating its presence. The wheel is kept in slow rotation by clockwork, and when the extra impulses induced in the aerial cease, the film of oil is again dragged in, and insulation is re-established.

Thus the decoherence is not entirely automatic, as it is in the case of carbon coherers, though it is uniform and continuous; for this reason it is far better than if it depended, like the decoherence of a filings-tube, on the cumbrous and clumsy device of an electro-magnetic tapper switched on by the current detector.

Sir Oliver Lodge and Dr. Muirhead have always preferred methods of continuous decoherence by

clockwork to the relay and tapper method, and before the wheel coherer was invented they did very successful work with a filings-tube coherer, a clockwork decoherer, and a siphon recorder.

The current detector used at the present time in the Lodge-Muirhead system is the siphon recorder, which is simply a moving coil instrument or modified d'Arsonval galvanometer provided with a fine bent siphon tube of glass, so arranged as to record the motion of the coil on a moving strip of paper on which one end of the tube rests lightly, while the other dips into coloured ink. The clockwork which draws the tape through the instrument also serves to drive the rotating coherer disc, to which it is geared by toothed wheels of ebonite.

In the apparatus described below the rotatory motion of the steel wheel is supplied by separate clockwork, and the motion of the instrument coil is observed by means of an attached pointer bearing a small flag.

A full account of the apparatus, as used in the Lodge-Muirhead system, will be found in the book mentioned on page 68.

Receiver Used in the Hampstead and Tufnell Park Installation.

Fig. 22 shows the Lodge-Muirhead coherer reduced to its simplest possible form, as it was used in the installation which already has been partly described.

The whole apparatus used for receiving at Tufnell Park was crude and simple, and could be constructed by anyone possessing a moderately good lathe and some common-sense.

The photograph speaks for itself: Two uprights

of brass soldered to a brass base carry adjustable pivot-sockets at their upper ends, and a sharp-edged steel wheel, turned out of a short length of rod in one piece with its shaft, is pivoted at both ends and runs in the said sockets.

The mercury container consists of a short piece of ebonite rod drilled longitudinally to a depth of about 1 in. and slightly hollowed, or cupped, round

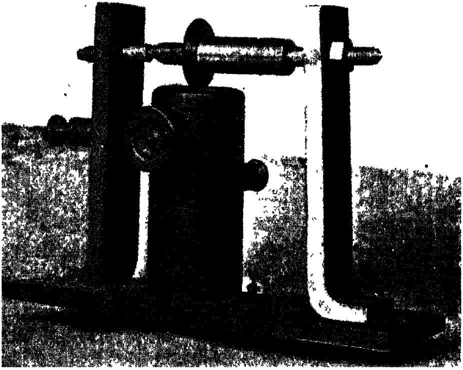


FIG. 22.—Simple Wheel Coherer, used $1\frac{3}{4}$ miles from Transmitter.

the mouth of the hole, which is about $\frac{1}{8}$ in. diameter and forms a tube for the column of mercury. Connection is made to the mercury by a small amalgamated spiral of platinum wire, which passes through a fine hole in the side of the container and projects into the mercury. The outer end of the platinum

wire is held under a terminal, which is screwed into the side of the container.

Contact is made with the wheel by means of a small copper brush (not shown), which was attached to the brass uprights and pressed upon the stout shaft of the wheel. Connection was made with the brush by means of the terminal shown on the left in the photograph.

The level of the mercury can be adjusted by means of the ebonite screw seen in front; this enters a threaded hole communicating with the vertical tube, and by screwing it inwards the mercury behind the screw would be forced into the container, causing the level of the rounded surface at the top to rise. This device, which the author has found useful even in a properly constructed coherer provided with arrangements for raising and lowering the container itself, was suggested by Mr. A. C. Lock. This detector works well over short distances where great sensitiveness is not essential; but the method of making connection with the mercury is bad, and pivots of such design and for such a purpose are sure to give trouble sooner or later, however carefully made. The potential-divider consisted of a length of high-resistance wire connected to a single accumulator cell and provided with a sliding contact; the current detector was an ordinary telephone, the connections of the circuit being as shown in Fig. 23, where A A lead to the upper and lower capacity-areas, C is the coherer, T the telephone, P the potential-divider, and B an accumulator cell. When a telephone is thus employed as a current detector, a very serious difficulty is met with, though the extreme

simplicity of the apparatus might suggest that one has but to make an adjustment or two and then receive signals. There is, in fact, no difficulty in getting signals, but those which come are too often unintelligible, even to one practised in reading the Morse Code.

The reason for this is as follows :—

When a torrent of sparks occurs at the transmitting station, each spark is accompanied by a train of waves, which induces oscillating currents in the receiving aerial. A dash will be made up of a long series of trains of waves, and a dot will consist of only a few.

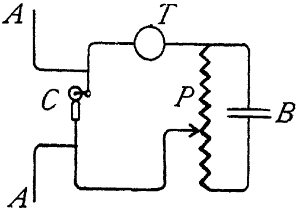


FIG. 23.—Connection for Simple Receiving Circuit.

Now when the contact between wheel and mercury is roughly adjusted, the first train of waves in a group causes coherence, and decoherence does not take place before the second train arrives and renews the conducting condition ; again, the third train does its work before the rotation can undo that of the second train. Thus the coherer is in a continuously conducting state during the whole period of arrival of each group of wave-trains, and does not become decohering until that group ceases. This behaviour

is all that could be desired where a galvanometer, siphon recorder, or other moving coil indicator is used, and ensures a steady and long deflection for each dash and a short one for each dot; but when a telephone is substituted as a current detector, a click is heard as the diaphragm is pulled down by the action of the first train of waves, and it is held down until the last train of the group has died away, when it is released, giving a second click.

Thus, instead of a series of rapidly succeeding clicks distinguishable as a dash, there is a dot, followed by a pause and then by another dot. Sometimes slight variations cause an erratic crackling during the pause, but they do not become properly distinguishable.

Day after day signals were sent by the hour from Hampstead to Tufnell Park, an exact log of all that was sent or received being kept at both stations.

A sample taken from one of several pages of these records will serve to show the utterly confusing effect of the dashes arriving as separate dots. These experiences indicate, and later ones prove, that the best spark length was from $\frac{3}{8}$ in. to $\frac{1}{2}$ in. The slight discrepancies between the times recorded at the two stations were, of course, due to a difference between the watches used.

(1) *Sending*.—12.30–12.35—spark length, $1\frac{1}{8}$ ins.; signal sent, V; remarks:—sparks very rare of occurrence and almost ceasing when signals were stopped at 12.35.

Receiving.—12.31, slow; 12.32, desultory; 12.33, still distinct; 12.35, signals stop; signal received, E.

(2) *Sending*.—12.36–12.41—spark length, $\frac{7}{8}$ in.;

signal, I; remarks:—signals sent at perfectly regular intervals.

Receiving.—12.35½, start less loud, but perfectly clear; signal received, I; 12.37½, quality the same, intervals perfectly regular; signal received, E; 12.40, regular, clear I's; 12.40½, signals stop.

(3) *Sending.*—12.42–12.45—spark length, ⅝ in.; signal, M.

Receiving.—12.41¾, very distinct, quite as good as (1); signal received, H; absolutely distinct. 12.43, quickens; signal, S; then S in couples at long intervals; 12.44, S, very clear at long intervals; 12.44½, signals stop.

A brief examination of these results with reference to the Morse Code (see appendix) will show that whatever signal was sent from Hampstead, the letters received almost always appeared to be those made up entirely of dots.

When at last the cause of the trouble was discovered, various fruitless attempts were made to get readable dashes; among other things, the current allowed to pass through the coherer was decreased, the speed of rotation of the wheel was varied within wide limits, and vibrating contacts were inserted in the circuit to break up the continuous current and give the required buzz.

None of these methods were found satisfactory, and eventually the telephone was abandoned and a modified d'Arsonval galvanometer was substituted, but the inertia of the coil was considerable and the methods of suspension unsuitable, so that the signals were almost as badly confused as formerly. Since that time the author has learnt that a well-made wheel coherer can be used with a telephone if the

edge grazes the mercury extremely lightly, and if the voltage is reduced considerably below the value which is suitable for other current detectors. (See page 130.)

The coherer used in the above experiments would be quite unsuitable for telephone work, because the grazing needs to be so slight as to necessitate absolute truth and smoothness of the wheel edge. It is no easy matter to turn a wheel true enough for telephone work, though the Lodge-Muirhead wheels put on the market by the Company are often tested for truth by means of a telephone; but even if a true wheel is produced, it is hopeless to mount it in ordinary pivots such as an amateur can make. Since the experiments at Tufnell Park were carried out, the author has constructed the receiver which is about to be described, and has found it far more sensitive and satisfactory than the above, the difficulty of obtaining readable signals having been entirely surmounted.

A Lodge-Muirhead Receiver.

The Coherer.—In Fig. 24, *a* and *b* are the elevation and plan respectively of the coherer, the construction of which is as follows:—A is a piece of ebonite, $1\frac{7}{8}$ ins. by $1\frac{1}{2}$ ins. by $\frac{15}{32}$ in., in which a slot B, $\frac{15}{32}$ in. wide, has been cut vertically downward in the centre to about $\frac{1}{2}$ in. from the bottom. A piece of ebonite, C C, $1\frac{1}{2}$ ins. by $\frac{15}{32}$ in. by $\frac{3}{8}$ in., fits across the top of A, bridging the slot. C C is secured to A by the screws D D. A $\frac{1}{8}$-in. hole is drilled vertically through the centre of C C, and a $\frac{1}{8}$-in. brass spindle E passes through the hole and is provided with an ebonite head G; this is held

FIG. 24a.

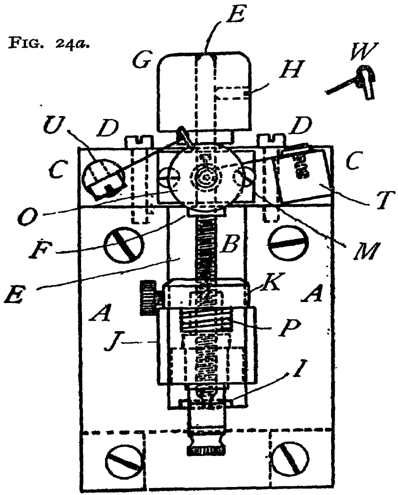


FIG. 24b.

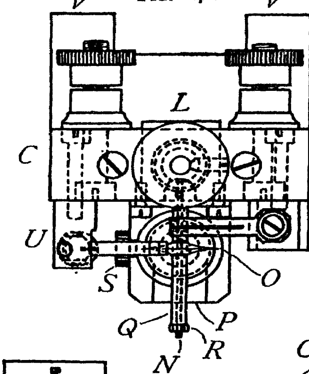
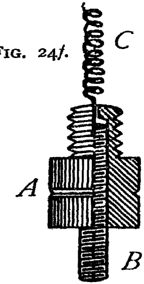
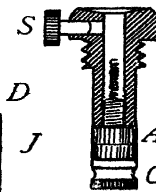


FIG. 24f.





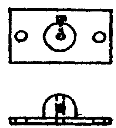


FIG. 24d.

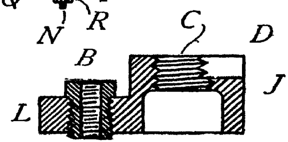


FIG. 24c.

FIG. 2ε

by the setscrew H, which drives on to a slight flat filed on the spindle E, and is sunk so that the top of the screwhead is flush with the outside of G. The portion of E which projects below C C is threaded, and a small collar F is screwed tightly at the top of the thread, so that by adjusting the position of G on E the spindle can be made to turn easily, but without freedom of vertical motion.

At the bottom of the slot a small brass plate I, drilled $\frac{1}{16}$ in. in the centre, is fastened by a screw, and serves as a bottom bearing for the spindle, the end of which is turned down to $\frac{1}{16}$ in. to run in the hole.

The holder J, into which the mercury cup K screws, is shown separately in sectional side elevation in (*c*) (actual size). It consists of an ebonite block with an enlarged portion projecting outwards in front of A (*a*), and a thinner and slightly narrower portion L (*c*), fitting into the slot B (*a*), so that it can slide nicely up and down without side-shake. The portion L (*c*) is fitted with a bush B, which is screwed into it and drilled and tapped through the centre to take the threaded spindle E (*a*). Thus, on rotating the spindle by means of the head G (*a*), the height of the projecting block J can be varied at will.

A hole C (*c*) is drilled vertically through J, and tapped $\frac{3}{8}$-in. Whitworth. This hole must be exactly under the edge of the wheel O (*a*), so that the dimensions of J must depend upon the position of the wheel if the wheel is fitted first, and *vice versa.*

The hole is enlarged underneath so as to leave only a few turns of thread for the screwing in of the mercury-holder or cup K. This saves time in removing K for cleaning and in replacing it, but

what is more important, it enables it to be unscrewed and removed without getting it jammed against the wheel. For the same reason a portion D (*c*), P in (*a*) and (*b*) at the front of the upper edge of the hole C is cut away to enable the cup K to be tilted forward and taken out in a slanting direction after it has been unscrewed. The photographs will help to make these points clear.

The mercury cup K is shown in part section (actual size) in (*e*). The enlarged part is $\frac{1}{2}$ in. diameter and about $\frac{7}{32}$ in. deep; it is slightly concave at the top, like a very shallow funnel, and the upper outside edge is bevelled.

Beneath this part there is a length of about $\frac{3}{16}$ in., which is turned down to $\frac{3}{8}$ in. and threaded to fit the $\frac{3}{8}$-in. tapped hole C in the holder J.

The remaining portion, $\frac{3}{8}$ in. in length, is turned to a diameter of $\frac{1}{4}$ in. A $\frac{1}{8}$-in. hole is drilled centrally through from end to end, and is then slightly enlarged at the bottom and tapped to $\frac{5}{32}$ in. to take the knurled ebonite stopper A. The stopper A carries the platinum spiral seen in the centre of the vertical hole which forms the containing tube for the column of mercury.

The knurled stopper A, shown twice the actual size and in half-section in (*f*), is of ebonite about $\frac{1}{4}$ in. diameter, and is shouldered down to $\frac{5}{32}$ in. and threaded to fit into the bottom of the mercury container. It is drilled and tapped to within $\frac{1}{16}$ in. of the upper end to take a short length of threaded brass B, to the upper end of which a length of fairly thick platinum wire (such as is ordinarily used for chemical work) has been soldered.

A fine hole is drilled in the top of A, and the

platinum wire is thrust through it from beneath, B being screwed home tightly so that the terminal head C, shown in (*e*), shall have no chance of shifting it. The platinum wire is neatly coiled in a fine and rather close spiral C, and the fine hole through which the platinum projects is carefully stopped and covered over with hot shellac.

This arrangement prevents the mercury in the container from becoming contaminated by amalgamation with the zinc in the solder or in the brass, for it touches nothing but platinum, ebonite, and shellac.

The platinum spiral must be small enough to pass up into the container without touching the sides. Fig. 24 (*e*) shows a small terminal head C turned and tapped to screw on to B; this is for making connection between the mercury column and the rest of the apparatus.

A hole is drilled in the side of the mercury cup, and a tightly fitting plug, or, better still, a screw of ebonite with a milled head S, is fitted therein, the purpose of this being as explained in the case of the coherer described on page 85.

M in Fig. 24 (*a*) is a small brass plate screwed to the front face of C C, and provided with a boss which projects backwards into a recess drilled for it in C.

The plate and boss, which are shown separately in plan and elevation in Fig. 24 (*d*), are drilled through the centre to take the spindle N (*b*), on which the wheel runs, and the plate is drilled at the sides to pass the two screws which hold it to C (*a*) and (*b*). A very small setscrew is provided for holding the spindle firmly in the boss.

The spindle N, which may be made of a short length of rather small knitting needle, is threaded at the

tip and provided with a tightly fitting knurled nut R (*b*) at the end.

Over the spindle slides the sleeve Q, which carries the wheel O (*a*) and (*b*). It is slightly tapered towards the front, and is made sufficiently long to enable a pulley of ebonite to be driven on to it; the pulley is not shown in the drawings, but can be clearly seen in the photographs.

The sleeve Q should fit so as to turn on the spindle without the slightest shake and with the least possible friction, and the nut R must be adjusted with the same end in view.

The wheel O, about $\frac{7}{16}$ in. diameter, is turned out of file steel and ground to an absolute true and smooth edge. It is forced on to Q, and, if necessary, secured to it by neat and careful soldering. All superfluous solder must be turned off, and the final edge worked up with great care. Most amateurs will probably do best to get the sleeve and wheel turned by a *good* watchmaker, who should not charge more than three or four shillings. A watchmaker will also fit the nut R and the small setscrew shown in (*d*).

The wheel must be examined and tested with great care, and, if faulty, the edge must be worked up again by the experimenter himself.

This may be done either in an accurate lathe or by mounting it on a well-fitting spindle and rotating it by means of a watchmaker's bow. The edge must be sharp (though not quite razor-sharp), true, smooth, and not wired; in getting this result a very hard and sharp graver should be followed by fine Turkey stone and then by a piece of good leather with a little razor-sharpening paste on it.

Good results may be obtained with a wheel which is far from perfect, but the truer the wheel the better the work.

The block T of ebonite is held by a screw passing through C from the back, and carries a split brush of very thin springy copper. This brush presses on the sleeve Q, and its pressure must be so regulated as to make good contact without too great an increase of friction.

The pressure can be regulated by slightly loosening the screw which holds the block T, turning it to the correct angle, and again tightening the screw. The brush is held to T by a small screw, under the head of which is a washer. U is a short length of brass rod, which is held to C by a screw like that which holds the brush-block. A short length at the end of U is filed down to semi-circular section, and a small tongue of brass is held by a screw on to the flat so formed. The tip of the brass tongue is turned at right angles, and then folded over so as to nip a scrap of soft wash-leather, or felt, which it holds in light contact with the edge of the wheel. The method of nipping the leather is shown separately at W. The object of this very important detail is to keep the wheel clean, and free from clogged oil, etc.

A pair of terminals may be provided at the back, as shown, though the head C (*e*) gives sufficient facility for making connection with the mercury column.

The small base piece V is fastened at the bottom of A by means of screws passing through from front to back; the back of V is cut away in the centre for reasons which will appear later.

The foregoing is a description of the coherer

exactly as it was made, but experience gained in the course of using it and detailed examination of those at the Lodge-Muirhead stations, have made it clear that the construction could be slightly simplified. A few hints as to improvements will enable the reader to use his common-sense in altering the design given above, though the dimensions of the essential parts are entirely suitable.

The block J could be made to slide between a pair of vertical projecting slips fixed a short distance apart on the front of A. If a springy piece of metal were then fastened to the back of the holder J in

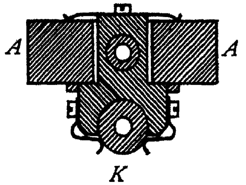


Fig. 25.—Alternative Arrangement of Wheel Coherer.

such a way as to bridge across the back of the slot B and hold J in firm contact with the front of A there would be no necessity for fitting L accurately into the slot B, making the whole construction considerably easier. Again, the housing of the mercury container could be greatly improved by doing away with the screw and arranging for the container to be pushed in from the front and held by a spring clip.

A rough sectional sketch embodying both these improvements is shown in Fig. 25, the parts being lettered as in Fig. 24.

The pulley (shown only in the photographs) is turned out of ebonite and drilled so that it can be forced on to the slightly tapered sleeve Q.

The diameter of the shallow groove in which the driving thread is to run will depend upon the speed and size of the pulley from which it is driven. If the sleeve Q has been badly fitted and the friction is considerable, the thread must run rather tight

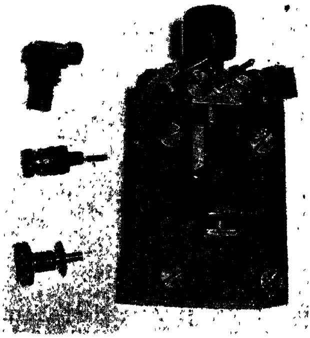


FIG. 26.—Coherer in Pieces, showing Wheel and Pulley, Mercury Container and Ebonite Stopper, with Platinum Spiral.

to prevent it from slipping; this will further increase the friction, thereby reducing the speed, unless the clockwork motor is one of considerable power.

The reader is recommended to use a pulley with three grooves of different diameter on the driving wheel and a one-groove pulley on the coherer wheel, as shown in the photographs.

None of the grooves should be much less than ½ in. in diameter, and in turning them the tool may be loosely held so as to chatter, or the groove roughened with the point of a file.

The speed of the coherer wheel can be varied within fairly wide limits without much alteration in the

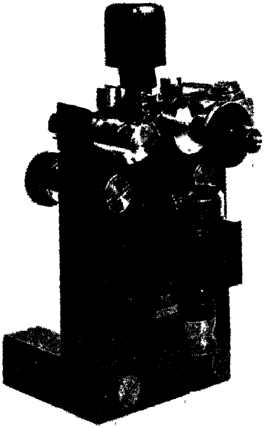


FIG. 27.—Lodge-Muirhead Wheel Coherer.

working, but is generally about one-half revolution per second.

The photographs, Figs. 26, 27, and 28, show the details of the finished coherer. In Fig. 26 the wheel, the mercury container, and the stopper carrying the platinum spiral are shown separately.

The Clockwork.—The ambitious amateur who attempts to make a siphon recorder will do well to gear his coherer directly to one of its wheels, either by pulleys, as described above, or by ebonite gear wheels. The latter may also be fitted to other clockwork, but under no circumstances must metal gear wheels be used, as the capacity effect of a large

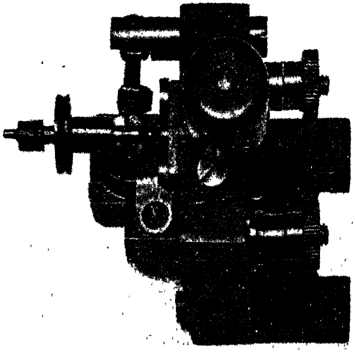


FIG. 28.—View Looking Down on Coherer.

piece of clockwork in direct connection with the coherer greatly reduces its sensitiveness. The clockwork used by the author was obtained for 10s. 6d. from the clock-department of Messrs. Smith and Sons, Clerkenwell. Though originally intended for rotating show-stands in shop windows, it is admirably suited to the present purpose, as it runs

for three or four hours with one winding. The slow-speed shaft which projected from the clockwork, and was arranged to carry the stand, was removed, and the wings of the high-speed fly (which is fitted with a double-threaded screw acted on by the last spur wheel) were cut away to a length of about $\frac{3}{4}$ in. to increase the speed of the clockwork.

The ebonite driving pulley was forced, friction-tight, on to the last spur wheel. The clockwork is held down to the apparatus board by a bridge of wood passing across from one side plate to the other, and screwed through its centre into the board. As the side plates are of different widths, one is blocked up by a slip of wood, but in the photograph the wheels hide both this and the bridge-piece. (Fig. 38.)

Some kind of simple arrangement must be fitted for starting and stopping the clockwork. Cheaper pieces of clockwork may be used as long as they can maintain the speed at a fairly steady value for a reasonable time.

Cheap phonograph motors have been used by the author, but are not suitable; the break requires special adjustment to give very slow rotation; otherwise the motor will run down too quickly. This adjustment is not easy, and even if successfully accomplished, the motor runs down before a long message can be received.

Better class phonograph motors running for longer periods are less unsuitable, especially if they are designed so that they can be re-wound while the clockwork is running.

Such motors do not compare favourably with weaker pieces of clockwork running for longer periods.

Current Indicators.—The next step is to provide some piece of apparatus which will indicate the presence of the intermittent currents which pass through the coherer; and as it has to show successions of long and short signals following each other somewhat rapidly, the indicating part must move sharply over a small range. It must also be "dead beat"—that is, it must move over the short distance of travel and come to rest without either swinging or rebounding if a stop is used. The sensitiveness needs to be sufficient to give easily readable indications.

Galvanometers.—Ordinary moving needle galvanometers are seldom of any use for this purpose, as they are usually either insufficiently damped or too slow in their motions. A suspended d'Arsonval or moving-coil galvanometer might be used if sufficient resistance were introduced to limit its motion to a very short range, but for really satisfactory working the best combination of qualities is attained by a pivoted moving-coil instrument described below.

Relays.—A relay and Morse sounder or inker may be used, but though the wheel coherer is more sensitive than a reliable filings-tube, the current taken by it when it breaks down is rather smaller than that which can be passed through a filings-tube used for rough work. Therefore, the relay must be sensitive, though its resistance need not be more than 80 or 90 ohms. The ordinary cheap instruments are not usually adequate, but a polarised relay, properly made as described on page 139, ought to work well with the wheel coherer.

Telephones.—The simplest way of receiving is by telephone, but the coherer must be extremely

well made, and the adjustments fine for successful working. (See pages 80 and 130.)

The Moving-coil Indicator.—When a uni-directional current passes round a coil which is suspended in a magnetic field with its plane parallel to the lines of force in that field, it tends to turn itself so as to enclose the greatest possible amount of magnetism; that is, to a position in which its own magnetic field coincides with that in which it is immersed. An ordinary d'Arsonval galvanometer consists of a coil so placed between the poles of a powerful permanent magnet and suspended by a pair of fine metallic strips which lead in the current and also tend to hold the coil in the right position. The movements of the coil can be observed either by means of a pointer or by a mirror reflecting a spot of light in the well-known way. If the coil be mounted between pivots, and provided with hair springs which control its motion and lead the current to it, and if arrangements be made for its movements to take place in a uniform field, its angular displacement is proportional to the current flowing through it: a pointer attached to it so as to move over a properly divided scale will, therefore, indicate the value of the current with great accuracy. Such an instrument is admirably adapted for reading very small currents, and if sufficiently sensitive can be used in conjunction with a Lodge-Muirhead coherer for wireless telegraphy, the long or short movements of the pointer giving sufficient indications of the dot and dash signals sent by the transmitter.

For this purpose the author has used a Johnson and Philips' moving-coil milliamperemeter with great success; the pointer, which was at zero when no

waves were being generated, moved across the scale over 4 or 5 ins. when the transmitter was at work.

The magnitude of the movements of the milli-amperemeter made the signalling excessively slow, and the pointer was too small for easy observation; better results were obtained, however, by reversing the connections so that the needle deflected backwards against the stop. It was also impossible to fit the coil with attachments for ringing up, and the instrument was needlessly expensive, as the scale, the calibration, and the various precautions to ensure accuracy were quite unnecessary for the purpose in question. The author will now proceed to describe the moving-coil indicator which was eventually made and used with his apparatus. Fig. 29 is the plan, and Fig. 30 is the front elevation, and shows nothing behind the dotted line A, Fig. 29, except the screws B. Fig. 31 is a side elevation showing a few details which could not be inserted in 29 and 30 without confusion; portions shown clearly in the other figures are here omitted. C is a permanent horseshoe magnet supplied with the aluminium former D by the instrument department of Messrs. Johnson & Philips, of Charlton, Kent; the cost of magnet and former being 7s. The amateur is not advised to attempt the construction of the magnet or to buy a cheap one of inferior quality. These magnets are forged and hardened by a special process, which gives excellent results, but cannot be done cheaply.

The former should be obtained with the magnet, as it is impossible to make one which so well combines lightness, continuity, and convenience. However, should the reader decide to construct his

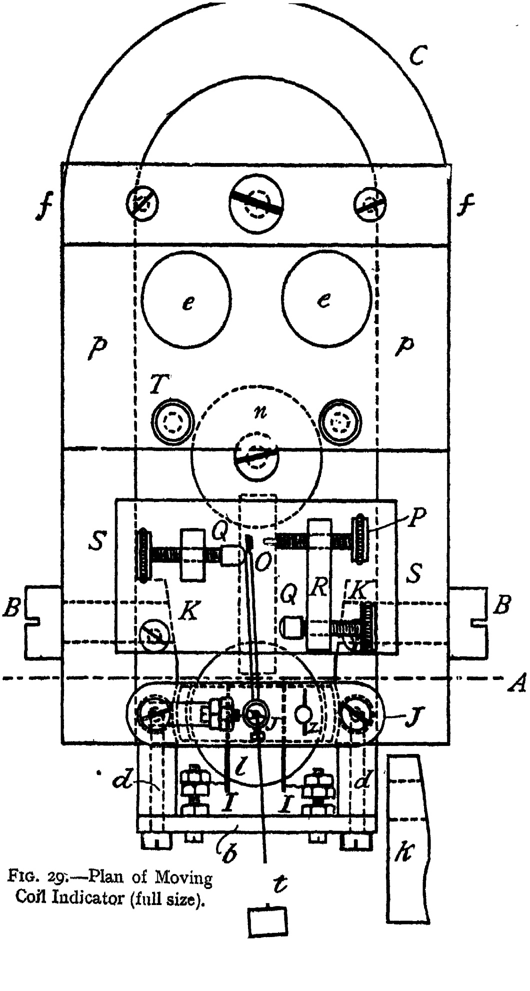


FIG. 29.—Plan of Moving Coil Indicator (full size).

own, it must be of metal bent to a rectangle with the ends well soldered together. Aluminium cannot be soldered in the ordinary way, and the home-made former should therefore be of copper or silver, as its conductivity must be high. The reason for this is

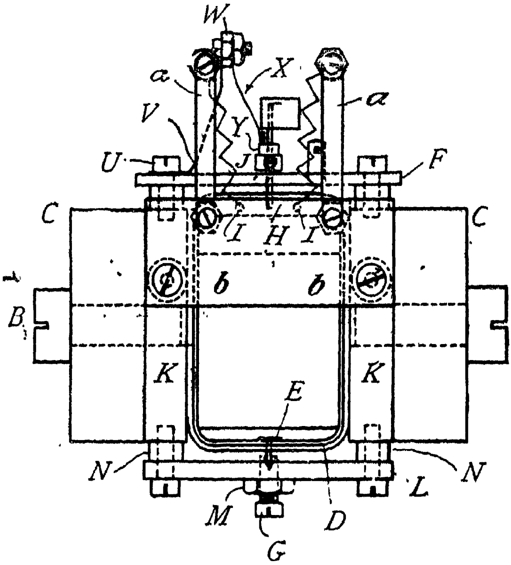


FIG. 30.—Front Elevation of Moving Coil Indicator (full size.)

that the former plays an important part besides that of holding the coil. During any change in the angular position of the coil a current is induced in the former, as it cuts the lines of force from the permanent magnet, and this current is always in

such a direction that the mutual action between its magnetic field and that of the magnet opposes the change. In other words, the former causes the moving coil to be heavily *damped*—that is, it behaves as if during its motion there were considerable fric-

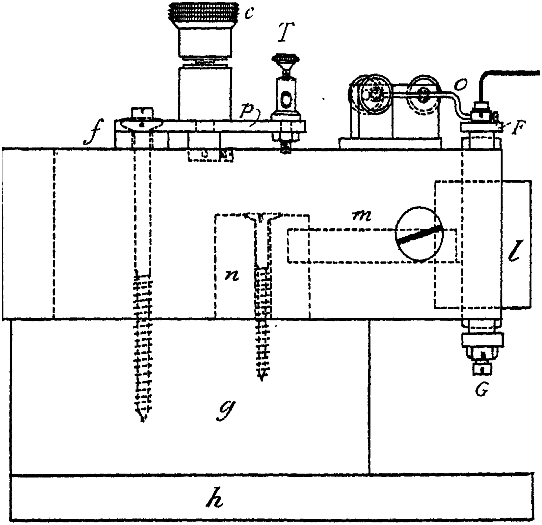


FIG. 31.—Side Elevation of Part of Moving Coil Indicator, three-quarters of actual size.

tion, preventing the tiresome swinging which would otherwise take place.

The aluminium former mentioned above is not very strong, and must be handled with care or it will get bent out of shape.

The next step is to fit top and bottom pivots to the former. This is done by riveting very small brass plates to the inner side of the rectangular frame, drilling and tapping a central hole through and screwing in steel pivots—the bottom one finely pointed and hardened, and the top one left unpointed. One of these plates is shown at E, Fig. 30. The bottom pivot need not be longer than is required to project beyond the coil winding and into the pivot-socket.

The top pivot, or, rather, spindle, which turns in a hole in the plate F, will have to carry a boss and a pointer, and should be left at least $\frac{3}{8}$ in. long, as it can afterwards be shortened if necessary. It should be parallel for about $\frac{3}{16}$ in. distance from the former, and should then taper away very slightly. It is most important that these pivots should be both central and in line, and if there is likely to be any difficulty in fitting them, the work must be done by a good watchmaker, who will also make the pivot-socket G, which is a $\frac{1}{8}$-in. Whitworth screw conically socketed and then hardened.

After a single coat of shellac varnish has been applied and allowed to dry, the former is ready to be wound. This is most easily effected by slipping it on to a rectangular wooden block mounted between two uprights, so that it can be turned round by means of a handle of bent brass rod; the handle should be slightly friction-tight in its bearings to prevent the coil from unwinding directly the handle is released.

The former must not be free to shift on the block, and, if loose, must be very gently wedged with thick paper.

The end of the wire (No. 40 silk-covered) is secured

to the wooden block by a drop of melted wax, and is then hitched over the turned-up edge of the former, a scrap of silk being inserted under it at this point for protection of the insulation. It is then very carefully wound on in a smooth layer, the turns being now and then pushed up together to avoid the slightest waste of space.

When the winding comes to within $\frac{1}{8}$ in. of the pivots, small pieces of silk are laid on the former and bent up in such a way as to allow turns to be slightly heaped up round the pivots without the risk of short-circuiting. The heaping, which is necessitated by the fact that the pivots occupy a small central space, must be carefully managed with each layer so as to get the turns on as neatly as possible; similar pieces must, of course, be placed on the other sides of the pivots.

Greater care must be exercised in winding outwards from the centre to the edge, as the curvature of the former tends to make the turns slip apart.

When the first layer is finished the wire is attached to the wooden block with wax and a second coating of shellac varnish is applied and allowed to dry for some hours, the process being completed by a very slight warming. After the varnish is hard the wire is detached by warming the wax, which is then cleaned off. A second layer is wound backwards over the first, with the same precautions, except that the original pieces of silk round the pivots are sufficient for this and all succeeding layers.

The second layer is varnished like the first, and in this manner five or six layers are put on. When the winding is finished the coil is slipped off the block, and a small strip of ebonite H is fastened on the

inside of the former and underneath the upper pivot by means of a little wax. It is further secured by a few turns of thread, which are tied round it and the coil together, and are then made firm by running a little wax over them with a hot wire. Before being placed in position enough of the central part of the ebonite is cut away where it bears up against the former, to give room for the brass pivot-plate. Two fine holes are also drilled through from front to back, and two short straight lengths of No. 22 copper wire I I are forced through so as to project about $\frac{1}{8}$ in. behind the coil. The two ends of the coil are brought round and over the edge of the former, and are soldered to the projecting wires I with about $\frac{3}{16}$ in. slack, so that on carefully pulling the pieces of stiff wire outwards from the front the slack ends are drawn into the holes in the ebonite, the connections being pulled tight. These ends must, of course, be protected by silk and varnish where they pass over the edge of the former.

The stiff wires I projecting in front are now secured in their holes by heating them and running in a little wax. The pole-pieces K K, shown separately at *k*, Fig. 29, are held to the magnet C by the screws B B, which pass through holes already drilled in the magnet as received from the works. K K are made slightly concave so that the coil shall be as near to them as possible without touching.

The pivot-socket at the bottom is screwed into the plate L, and this is clamped between the drilled cylindrical distance-pieces N and the heads of the screws which pass through them into the pole-pieces K K. The plate F, through which the upper pivot,

or, rather, spindle, passes is similarly secured to the upper surfaces of the pole-pieces. G is fitted with a locknut M, which holds it firmly when it has been properly adjusted.

Above the plate F the spindle is provided with a very small brass collar J, which is held to it by a setscrew in the front.

Into the opposite side of the collar is screwed an arm O, of rather thick aluminium wire, which bears at the end a piece of platinum wire or foil neatly riveted to it; in Fig. 31 the wire O is shown bent twice to raise the contact, but this would not be necessary if the spindle projected far enough above F. The arm O is for making contact with the screw P and for limiting the motion of the coil by means of the adjustable stops Q Q. P is provided with a platinum tip, which is fitted by drilling a small central hole in the end of the screw and soldering a short piece of platinum wire therein.

The screw is provided with a knurled head, and works in the vertical brass plate R, which is held by screws passing up from underneath the small ebonite base S. S is supported on the two pole-pieces K K, to which it is fastened by screws.

Another stop Q screws into the plate R, and is capped with a small piece of ebonite, on the tip of which is stuck a scrap of felt to cushion the arm O when it deflects. The back stop Q on the other side passes through a second narrower brass plate, and is similarly tapped.

The contact is for calling up, and forms part of a bell circuit; when its use is not required, it has only to be screwed back a turn or two so that O deflects against the stop Q.

T T is a pair of terminals to which the bell circuit is connected. One of them is joined to R by a piece of wire clamped under the head of the screw which holds R to S, and the other passes to one of the screws which holds the plate F down to the pole-pieces K K.

Under the left-hand screw U is held a narrow piece of thin brass strip V, provided with a No. 10 B.A. screw passing through a hole at the top and clamped to it by the nut W. Between W and a second nut is clipped a short piece of phosphor-bronze strip X, of the kind used for suspending d'Arsonval galvanometers.

A small and rather weak clock hair spring must now be obtained, and the little boss Y at the centre drilled so that it can be forced on to the tapered spindle of the coil. A minute hole must also be drilled vertically by the side of the central hole, to receive a very small tapered pin. The spring must be forced on very carefully, the coil being pressed upwards at the same time. On no account must the pressure be taken by the bottom pivot of the coil.

A small brass pillar Z is screwed into the plate F at such a distance from the spindle in the centre that the outermost turn of the spring can be thrust through a hole drilled in it from front to back.

The drawings show a taper pin, which can be driven into this hole to grip the hair spring when its tension has been properly adjusted. The control exercised by the spring must only be sufficient to bring the coil to the position of rest with a fairly crisp motion. If the control is too great the spring must be rejected and a weaker one chosen. (To avoid confusion the hair spring has been omitted from

the drawings.) When the hair spring has been properly adjusted and fastened, the piece of phosphor-bronze strip X is inserted in the small side hole in Y, another taper pin being pushed in so as to hold it firmly in contact with Y; X, of course, must be slack enough to allow free motion of the coil. The object of the phosphor-bronze is to provide a third path for the bell-current, which would otherwise divide between the hair spring and the bottom pivot; the point of the pivot would then possibly get hot, especially if the contact were used for carrying larger currents than that of a bell.

Connection is made to the coil in the following way. The ebonite plate *b* is held against the drilled cylindrical distance pieces *d d* by screws which pass through into the pole-pieces K K. The plate *b* carries the two narrow vertical strips of thin brass *a a*, which are secured to it by No. 10 B.A. screws and nuts; the latter also serve to hold a pair of thin wires which lead to the large terminals *e e*.

The tops of the brass strips are each provided with a No. 10 screw with two nuts, between which a piece of phosphor-bronze strip is held as X is held in W. Each piece of strip is zig-zagged for the sake of flexibility, and is soldered at its lower end to the tip of the wires I I, which form the terminals of the coil. Thus there is complete connection from the terminals *e e* to the moving coil, though the phosphor-bronze strips exercise practically no control over its motion.

The terminals *e e* are ebonite-cased, but ordinary brass ones will answer the purpose equally well. These, and also the bell-circuit terminals T T, are carried by an ebonite plate *p*, which is screwed to

a strip of thick brass *f*, the ends and the back edge of the brass being flush with the edges of the ebonite.

A hole is drilled through the ebonite and brass strip at the centre of the latter, and through it a long and stout brass screw passes down into the wooden block *g*, thus holding the terminal plate *p* firmly to the magnet and the magnet to the block. The block itself is fastened by screws to the base-board *h*.

It now remains to place in the centre of the coil a cylinder of soft iron *l*, filling the space as nearly as possible without actually touching; the object of this is to increase the magnetic flux acting on the coil. This cylinder is supported by a ¼-in. brass rod *m*, which is screwed into a radial hole drilled in the iron. The other end of the rod is screwed into an ebonite block *n*, which is held down by a brass screw passing through the centre into the wooden block *g*. To complete the instrument all that is required is a long arm of aluminium wire *t*, carrying a small flag at the end and fastened to the top of the coil spindle with hard wax. The flag should be of white paper, about ½ in. square, with a broad black stripe down the middle, or half black and half white.

Though the apparatus could be simplified by doing away with the bell-contact, this is a useful addition, and the whole instrument is much easier to construct than the drawing might lead one to suppose.

Note.—The photographs, Figs. 32 and 33, show the brass upright V to which the strip X is attached on the *right*, but it is clearer in the drawing.

Simple Potential Dividers.—In its simplest form this is nothing but a long wire of highly resisting material, through which a continuous current flows

from an accumulator cell; different lengths can be tapped by a pair of wires leading to the coherer circuit. The voltage between the tapping wires is proportional to the amount of resistance between the tapping points.

Explanations of the principle of potential dividers mnst be sought under that heading (or that of potentiometers) in any good modern text-book.

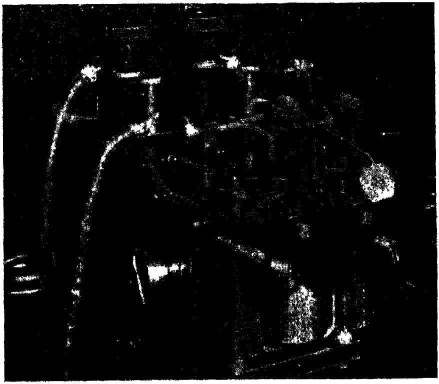


FIG. 32.—Moving Coil.

A perfectly practical potential divider could be constructed for the present purpose by stretching 5 or 6 yards of Eureka wire in a zigzag from one to another of a double row of wooden pegs fastened to a board, but the author proposes to describe a more convenient piece of apparatus in which permanent tappings are taken to studs, so that a rotating contact-arm can be shifted round a circle giving voltages rising by small steps from ·1 up to 1 volt.

The Potential Divider.—The ebonite base A (Figs. 34 and 35) is $4\frac{1}{2}$ ins. by 3 ins., though the reader is recommended to make it an inch wider—to avoid cramping underneath. When A has been nicely

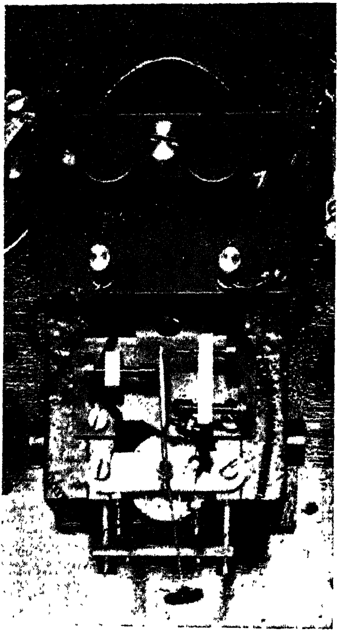


FIG. 33.—View, looking down on Moving Coil Indicator.

squared and finished, a circle is struck out and divided into twelve parts, eleven holes being drilled and tapped to take $\frac{3}{16}$ in. Whitworth screws.

The twelfth hole B is drilled rather nearer the centre of the circle.

Eleven cheese-headed $\frac{3}{16}$ in. screws are turned down until their heads are about $\frac{3}{32}$ in. thick and the edges are slightly bevelled, as shown in the drawings and photographs.

Each screw is drilled and tapped centrally at the end opposite to the head, so that small cheese-headed screws U can be inserted and wires gripped under their heads. Each $\frac{3}{16}$ in. screw is then driven tightly home in one of the eleven holes in the base A, the whole is mounted truly in a lathe, and a very light cut is taken off the bevelled heads of the screws.

There is now an almost complete ring of contact studs; into the remaining hole B an ebonite stud C is screwed so as to project above the brass studs, forming a stop for the revolving contact-arm.

A hole is drilled and tapped ($\frac{3}{8}$-in. Whitworth) at the centre of the circle of studs, and through it a length D of $\frac{3}{8}$-in. threaded brass rod, drilled through with a $\frac{1}{8}$-in. central hole and turned perfectly square at the ends, is screwed. D is secured by the locknut E, in two opposite flats of which holes are drilled and tapped radially to take small cheese-headed screws F F for holding connecting wires. G is a circular brass disc turned in one piece with the short length H, which is threaded ($\frac{1}{4}$-in. Whitworth). I is a rod of brass, which may be turned in one piece with G and H, or may be screwed centrally into the under side of G; it should turn easily, but without shake, in the central hole through D. J is a contact spring of stiff brass, or, better still, of phosphor-bronze. It is held firmly to

the under surface of G by three small screws, a hole, of course, being drilled through it to be slipped over the rod I. At this end it is rounded off to the same diameter as G, but it tapers towards the outer end, where the curvature is about the same as that of the studs. From the outer end to near the middle it is divided by two saw-cuts, which are best made by a fretsaw after very deeply scoring the track of the slits with a graver. K is an ebonite head drilled and tapped to screw tightly down over H on to G. L is a brass collar held to I by the setscrew M. L is also provided with the small cheese-headed screw N for making connection with it. The contact piece J is slightly bent, so that on pressing G down until J is level it makes thoroughly good connection with the studs.

The collar L is adjusted until J turns easily in D without freedom in a vertical direction, and then D is screwed upwards or downwards until the arm J is level. When these adjustments have been made D is locked by the nut E.

O is a short length of ordinary stranded flexible wire with the insulation removed; it is twisted up slightly, so that the strands shall not come apart, and its ends are then fastened under the screw N and one of the screws in the locknut E. It is adjusted until nothing is fouled by it when K J is turned completely round over the studs.

Four terminals T are now fitted to the ebonite base A, and connection is made from T^2 to the second screw in the locknut E. P P P are plug-blocks, which the reader will see are arranged so that the potential difference across the resistance R can be added to that which is obtainable from

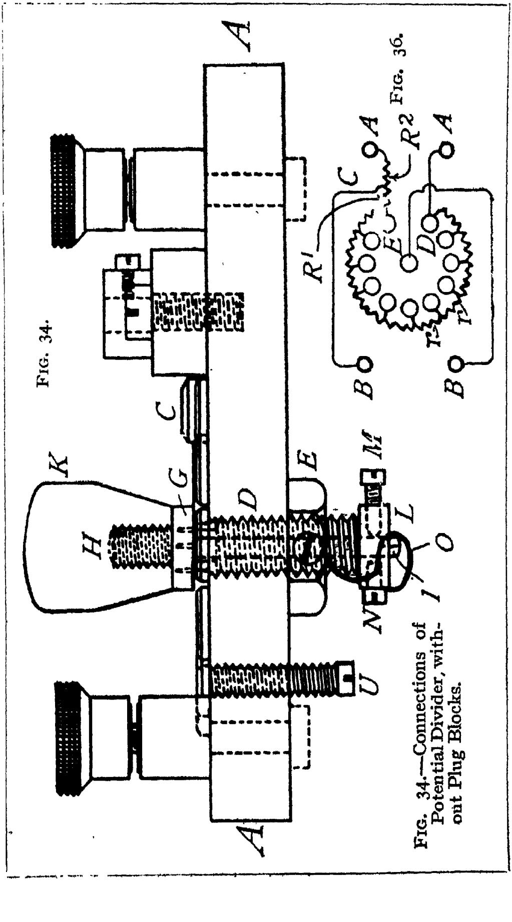


FIG. 34.

FIG. 36.

FIG. 34.—Connections of Potential Divider, without Plug Blocks.

the circle of studs alone. This refinement served a useful purpose in certain experiments carried out by the author, but is not necessary for ordinary working, and therefore a detailed description of it will be omitted. It has been inserted in the drawing as a hint to any reader who may wish to carry out experiments requiring a wider range or smaller division of potential difference than is afforded by the eleven studs.

Fig. 36 is a diagram of connections for the simple potential divider without the plug-blocks. A A are the terminals by which the potential divider is supplied with current from a single accumulator cell. The voltage of such a cell is 2, and the voltage available for the wheel should rise by steps of ·1 from ·1 to about 1.

Consequently, as resistance R^2 is inserted between one of the accumulators and the wire C, which goes to the terminal B and therefore to the coherer circuit, this resistance is about half of the total, so that there is a voltage of 1 between the wire C and the last stud D of the circle.

The resistances *r r r* between the pairs of studs are each made equal in value to R^1, and as they are ten in number there is a voltage of about $\frac{1}{11}$ between each stud and the next, or, as the accumulator gives rather over 2 volts when properly charged, the value is ·1 volt.

Thus, when the contact-arm is on the stud E it is tapping off a voltage of ·1 from R^1; if on the second stud, the voltage is ·2; if on the *n*-th stud, the voltage is *n* by ·1. The contact-arm is connected, as shown, to the terminal B.

The total resistance should be about 90 ohms;

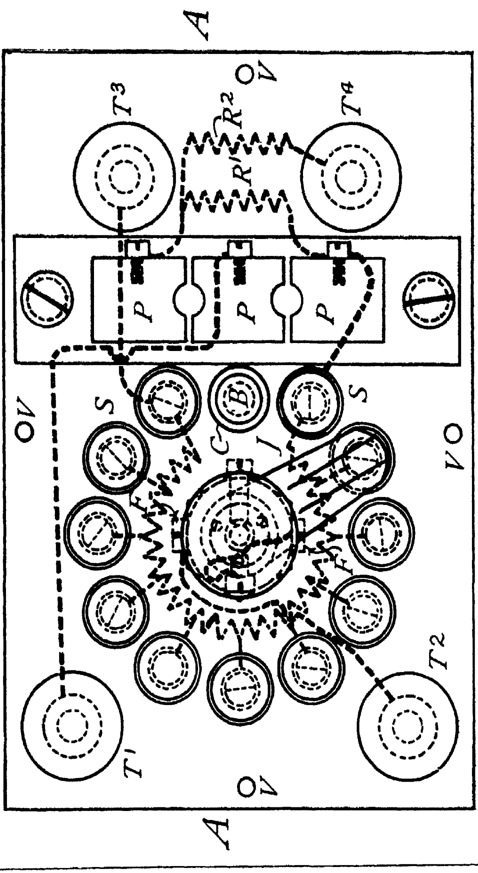


FIG. 35.—Plan of Potential Divider.

R^2 must therefore be 45 ohms, and R^1 and each of the other pieces 4·1.

The author used a length of No. 42 Eureka wire, passing on from stud to stud and bared for $\frac{1}{4}$ in. at each point where it was to be fastened under a stud-screw U, Fig. 34.

The length of each piece was adjusted by electrical measurement taken before it was finally fastened, but as many readers will not have the apparatus necessary for this purpose they are advised to use a rather larger size of Eureka wire.

This will necessitate greater lengths of wire, and small inaccuracies in measurement will not cause such erratic values of resistance as when the pieces are shorter; moreover, the larger sizes are easier to handle.

On the other hand, it is not desirable that the wires shall be long enough to require winding on bobbins, though one must be provided for the resistance R^2.

This bobbin, which is not shown in the drawings, should be firmly held to the underside of the base A by a screw passing through its central hole and into the ebonite. The wire must be wound doubled on itself in the well-known manner described in text-books; the ends must be soldered to lengths of stout copper wire, which are pushed through holes in the flange. The coil is then bound round tightly with silk tape in such a way as to prevent all possibility of strain or short-circuiting of the wire, and the whole is basted with hot paraffin wax. The last piece of loose wire R is soldered to one of the copper wires from R^2, the other being connected to one of the terminals A.

The remaining connections are obvious. The wires running round the studs may be bent to zigzags or disposed of in any way which is convenient, so long as there is no chance for them to short-circuit or get in the way of the central moving parts underneath the base.

For guidance as to size and length of the wires, the resistances in ohms per foot of three of the many

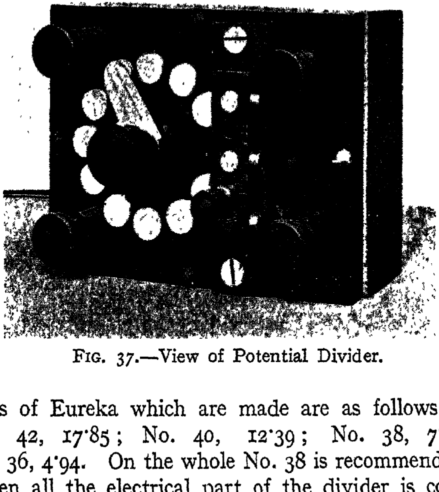


FIG. 37.—View of Potential Divider.

sizes of Eureka which are made are as follows:— No. 42, 17·85; No. 40, 12·39; No. 38, 7·9; No. 36, 4·94. On the whole No. 38 is recommended. When all the electrical part of the divider is complete it only remains to construct a neat wooden box of the same outside dimensions as the base A and deep enough to accommodate all that is fastened underneath it.

The holes V V are drilled in the base for screws, which pass through them and are driven into the edges of the box. Fig. 37 is from a photograph of the potential divider taken before the ebonite stop B was added.

Connections and Arrangement of Apparatus.—Fig. 38 is from a photograph of the complete apparatus, and Fig. 39 is a diagram of the connections. By following these figures together the working of the whole will be easily understood.

The board on which the apparatus is mounted has two cross-pieces screwed on underneath near the ends, and channels must be cut in these for the various wires, most of which run under the board. When all connections have been made a second board of the same size is screwed to the cross-pieces, care being taken to keep the screws clear of the wires, which by this means are kept out of the way and protected. Good quality bell wire of a dark colour should be used, the ends being neatly bared and the frayed cotton cut off.

T_3 is a pair of large terminals to which the aerial and lower-capacity area are connected. Beneath the board these terminals are joined to another pair, T_4; these are provided for the easy disconnection and removal of the coherer C, to which they are joined by thin wires above the board.

L_1, L_2 in the diagram are tightly coiled helices of wire underneath the board, and they help to confine the wave-induced oscillations to the coherer.

When the coherer becomes conducting, the current flows from P the potential divider through L_1, C, L_2, and, if the change-over switch S_2 is in the position drawn, through the coil of the indicator R

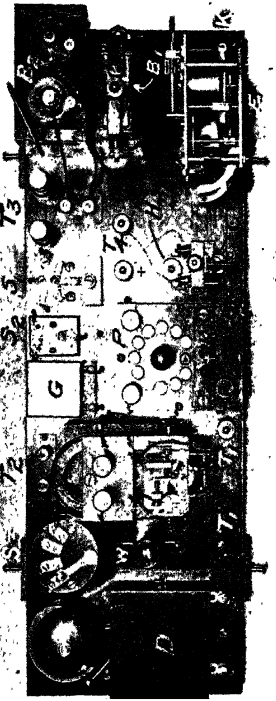


FIG. 38.—View of Complete Lodge-Muirhead Receiving Apparatus.

B_1—Accumulator Cell.	G—Testing Buzzer.	P—Potential Divider.
B_2—Bell Battery.	H—Screw Clamp for holding Coherer.	T—Terminals.
C—Coherer.		S—Switches.
D—Call Bell.	K—Buzzer Key.	W—Resistance.
E—Clockwork.		

and back to the potentiometer. The other contact of S_2 is for connecting the terminals T_1 in place of the indicator R. Thus, a milliamperemeter, telephone, or other apparatus, can be used instead of R. The potentiometer P is supplied by the accumulator cell B_1 which, by means of the change-over switch S_1, can be placed in series with a resistance

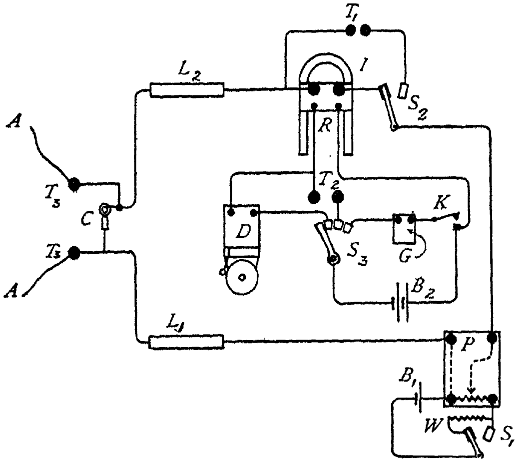


FIG. 39.—Diagram of Connections for Lodge-Muirhead Receiver.

W; this halves the potential differences obtained from P. This device, like the plug-blocks previously mentioned, is not needed for ordinary working, and may be left out, a single-way switch being substituted for the two-way shown. When the current flows through R a deflection is produced,

and remains as long as a continuous stream of wave-groups is affecting the coherer. Thus a long stream will hold over the indicator, showing a dash, while a short stream will give a momentary deflection showing a dot.

Immediately on the cessation of the waves the rotatory motion imparted to the coherer wheel by the clockwork E separates the contact-joint between the wheel and the mercury, and insulation is restored.

For calling up, the screw P, Fig. 29, is moved forward so that the contact attached to the moving coil shall touch P instead of the insulated stop; also, the switch S_3, Figs. 38 and 39, is closed on the first point, thus completing the circuit of the battery B_2 (two dry cells) and the bell D.

The coils of D must be shunted by a coil of about 18 ins. of No. 42 Eureka wound non-inductively as described above (see text-books). If this precaution be not taken, the waves generated by the self-induction spark at the bell-contact may keep the coherer in a continually conducting state, and the bell may go on ringing after the waves have ceased. If this is not effective, the bell-contact must also be shunted, but with 3 or 4 ft. of the same wire.

The effect of the non-inductive shunt is to provide for the inductive rush a comparatively easy path, in which its energy is converted into heat instead of generating waves.

By changing over S_3 to the second contact the terminals T_2 are substituted for the bell, so that an external bell, a relay for firing a cannon, or any other suitable piece of apparatus, can be set in action.

The third contact is connected to a separate circuit

consisting of the same battery B_2, the testing "buzzer" G, and a tapping key or bell-push K.

The buzzer is a very small electric bell with the hammer arm and gong removed and the contact arranged to vibrate with rapidity and regularity. When K is depressed this bell generates very feeble waves, which, however, are near enough to the coherer to affect it strongly.

Thus the receiver can be adjusted very conveniently by the operator before he connects the aerial wires to T_3; the adjustments are less easy to make by the incoming waves from the aerial, for these may or may not be arriving, and are at any rate not coming at known intervals.

The coherer is held in position by means of a very large terminal head H, which screws on to a brass shank standing up from, and firmly fixed in, the baseboard. This shank is arranged to stand in the space between the two projections V V, Fig. 24, so that the coherer can be clamped in various positions within certain limits.

Adjustments and Reception.—(1) Unscrew the stopper, Fig. 24, *f*, from the mercury holder of the coherer and raise the end of the platinum spiral to white heat in a spirit or bunsen flame; while white hot, plunge it quickly into mercury which will be visible on the spiral if amalgamation is successful. Replace the stopper and fill the container with mercury, giving it a tap to ensure the latter getting to the bottom. The column of mercury should project with a curvature slightly flatter than a semicircle. Replace the mercury holder.[1]

(2) Start the clockwork, put the driving thread on the pulleys, and adjust the position of the coherer

until the thread is stretched just tight enough to prevent it from slipping. A very little machine oil should have been placed previously in the bearings of the wheel.

(3) Screw up the container by means of the head G, Fig. 24 (*a*), until the wheel grazes the top of the mercury.

(4) Apply a drop of oil to the edge of the wheel, and wait until it is evenly distributed round the wheel.*

(5) Connect the coherer to the terminals T_4. These should have been marked + and − ; so also should the wires which go to the accumulator terminals, so that the polarity of the terminals T_4 may be always the same. Connect the + terminal to the brush which presses on the spindle of the steel wheel and the − terminal to the mercury column.

(6) Close the switch S_1, and change S_3 over to the buzzer circuit.

(7) Give promiscuous dot and dash signals by pressing K, and gradually increase the potential difference from P until the deflections of R exactly follow the motions of K. Increase the P.D. (potential difference) until the indicator R shows signs of lagging, that is, remaining deflected when no waves are sent, then decrease the P.D. slightly. The right P.D. is the greatest which can be applied without any of this "lagging," and is usually about ·5 volt.

(8) If the working is unsatisfactory, try very slight alterations in the height of the mercury container. If the P.D. is much less than ·5 volt, or

* The oil used for the coherer is a mineral lubricating oil, the density being about ·89.

the working erratic, try a little more oil. If the working is still unsatisfactory, there is probably something radically wrong with construction or connections, for the apparatus described is so simple and certain in action that refinements of adjustment are not necessary.

The Use of a Telephone.—A telephone may be used instead of the indicator by connecting it to the terminals T_1 and changing over the switch S_2.

The needful adjustments are different from those required for the indicator. A lower E.M.F., ·1 volt or even less, is required for this purpose, and the contact between mercury and wheel must be very finely adjusted, so finely that the slightest inaccuracy in the construction of the wheel will seriously interfere with its working. In fact, the Lodge-Muirhead operators test their wheels by receiving with a telephone.

A comparatively badly made wheel will operate with a moving coil indicator, and with a telephone will give clicks at the commencement and finish of groups of wave-trains (see page 87), but the adjustments required for getting readable signals must be so fine that decoherence takes place after each spark at the transmitter. Thus a dash will be heard as a long buzz or crackle, and a dot as a short one. If a perfectly even buzzing sound can be obtained all round the circumference of the rotating wheel, and if when the waves cease there are no periodic clicks due to minute roughnesses on the edge, the wheel is a very good one.

If such results are not obtained, the wheel may still be accurate enough for good working with the indicator R.

When the above tests have been carried out,

the wires leading to the two networks may be connected to the terminals T_3 and the messages received.

It is hardly necessary to add that for working about the house and to the bottom of a garden, etc., stout copper wires or brass rods, long or short according to the distance, may be connected to the terminals T_3 in place of the two large capacity-areas.

Other Tests.—The call-circuit is tested by changing the switch S_3 to the first contact, as described above, and screwing forward the contact of the indicator R.

The circuit, including the terminals T_2, can be tested by changing S_3 to the first contact and connecting a bell across T_2.

Heavy-current Relay for Fuses and Lamps.—For making the receiver switch on lamps, blow fuses, etc., an old bell may be adapted in the following simple way:—

Mount the bell on a vertical board with a stand, so that the armature is horizontal, the magnet-pull being in a downward direction.

Remove the contact, and bring the two ends of the magnet-winding out to terminals on the board. Cut off the hammer knob, and bend over and down, the wire on which it was mounted, so that when the armature is pulled down the wire dips into a mercury cup.

The armature and cup are connected to a pair of terminals, which are inserted in the circuit of the lamp or fuse.

The coil terminals are connected to the terminals T_2, and when the moving coil makes contact and closes the circuit of the battery B_2 and the terminals

T, the armature is attracted and closes the mercury switch.

Fuses for Explosion Experiments.—For blowing up cartridges or firing cannons, a convenient fuse can be made by soldering a short length, say $\frac{1}{8}$ in., of the finest platinum wire to two pieces of No. 26 copper wire. These are laid one on each side of an ordinary wooden match, so that the platinum wire bends over the head of the match and lies in contact with it. The copper wires are then bound to the match with cotton, and a little electrician's wax is run round to secure them, care being taken that none gets on the platinum or the match-head.

This fuse may be inserted in a cartridge, or in a small cup soldered over the touch-hole of a cannon and filled with powder, or in the touch-hole itself if large enough.

Connection is made to the fuse by twisting flexible or other wire on to the two ends of the copper, and the current to heat the platinum is easily supplied by one accumulator or bichromate cell, or even by a good dry cell.

Explosions should not take place near enough to the receiver for any risk of damage.

Precautions in using the Receiver.—No one should be allowed to handle the coherer wheel, as he will damage the edge and render re-sharpening necessary.

If the mercury or the wheel get badly dusty or the oil clogged, the container should be carefully cleaned and refilled, but the spiral should be re-amalgamated each time. It is as well to renew the mercury, and clean the wheel and container now and then, although it is wonderful how long the receiver may be put aside before it refuses to work,

if it be properly covered up (see page 7). When the apparatus is not in use, a paper wedge should be carefully inserted under the moving coil to lift the bottom pivot out of its socket and protect it from jolts.

The Cover.—A wooden cover-box should be constructed to fit over the baseboard, and strong hooks and screw-eyes may be provided for holding cover and board together. If these are properly fixed, the whole apparatus may be safely carried by a leather-bag-handle fixed to the top of the case, and so placed as to make the whole hang horizontally and in balance. The hooks must not be trusted

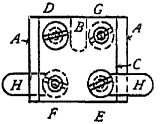


FIG. 40.—A Simple Filings Coherer.

until they have been arranged so that they cannot slip out of the eyes.

FILINGS COHERER APPARATUS.

A filings coherer of the type used by Mr. Marconi is not a very easy piece of apparatus to construct satisfactorily, and it is often necessary for the amateur to make two or three before he produces a successful one.

There are various simple types which are very easy to make, and one or two hints as to their construction may be given before describing the more reliable and sensitive tube-form.

Simple Coherer.—A small plate of ebonite, $\frac{5}{8}$ in. by $\frac{1}{2}$ in. by $\frac{1}{16}$ in. (A, Fig 40), is cut, and one side is

slotted to a depth of about $\frac{3}{16}$ in., the slot being about $\frac{1}{10}$ in. wide and rounded at the bottom, as shown at B. Small pieces of perfectly clean sheet nickel C are held on the two sides of the plate by the pairs of screws D E and F G respectively; the plates are drilled opposite the points of the screws to prevent short-circuiting. If lugs H H of sheet brass or nickel be fastened under the bottom screws at the back and in front, connection may be made to the plates by soldering or by providing them with small nuts and bolts. If preferred, the nickel plates can be cut with projecting lugs in the first instance.

It only remains to prepare some filings and drop a very small pinch in the slot B between the plates, and we have a simply made, efficient, and practical coherer. The filings are produced from a piece of nickel, a fairly coarse file being used. They should be well sifted through rather fine muslin, the dust and very small particles which get through being thrown away; *the filings retained by the muslin* are then sifted in a piece of rather coarser mesh, and *those which get through* are used for the coherer.

In this way only filings of fairly uniform size are used, and this is an important point which, if properly attended to, will help to ensure regularity and sensitiveness of working.

A few silver filings may be prepared in the same way, about 5 per cent. being mixed with the nickel; but they are not essential.

A minute pinch of the filings is now dropped into the slot, and the coherer is connected in series with a single Leclanché or dry cell B, Fig. 41, and a

simple galvanoscope or galvanometer G, which need not be very highly sensitive.

A foot or two of wire or metal-rod W is attached to each of the wires which lead from the coherer to the circuit, and extends outwards on either side, so that the two rods lie in the same straight line. In the diagram a tube-coherer is shown, instead of the one described above.

On setting a Hertz oscillator in action anywhere in the same house, there should be a strong deflection of the galvanometer, indicating a very considerable fall in the resistance of the coherer. This state of things will last until the coherer receives a slight mechanical shock, when the resistance will

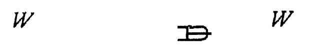


FIG. 41.
Simple Circuit for Filings Coherer.

rise to its original value and the galvanometer needle will return to zero.

The quantity of filings required for the best result must be discovered by experiment, as it depends on their size and on other conditions.

The coherer described above gets less sensitive as time goes on, owing to the oxidisation of the surfaces of filings and plates; this is necessary to a slight degree, as otherwise conduction would take place without the help of waves.

But when the coherer shows signs of insensitiveness, the plates must be taken off and cleaned and new filings prepared. This is not a very troublesome operation, and is not frequently required,

especially if the top of the slot be closed by a small well-fitted plug. Those who wish to avoid this, however, may adopt the plan introduced by Mr. Marconi.

The Marconi Coherer.—The Branly coherer in the improved form described in Mr. Marconi's 1896 Patent is the result of experiments on the best material and size of filings and plugs, and on the effect of hermetically sealing and exhausting the coherer to prevent undue oxidisation.

In its more recent form it consists of a small tube, Fig. 42, in which is a pair of tightly fitting nickel

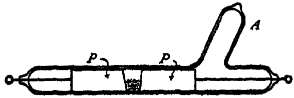


FIG. 42.
The Marconi Coherer.

plugs P P, to the outer ends of which short lengths of platinum wire are soldered. The faces of the plugs are filed at a slant, so that by rotating the whole tube on its axis the length of the little pinch of filings between them can be adjusted.

When this has been accomplished, the platinum wires are sealed into the ends of the tube; it is then exhausted from the annex A, which is sealed off when the vacuum has become moderately high.

When sealing in the platinum wires, they may be strengthened by bending them into a loop, the end of which is fused into the glass in the manner adopted in the manufacture of small glow lamps.

The internal diameter of the tube should be about $\frac{1}{10}$ in., and the distance between the plugs from 1 mm. to $1\frac{1}{2}$ or 2 mm., or from about $\frac{3}{64}$ in. to about $\frac{5}{64}$ in.

The plugs require very nice fitting in the tube,

as if they are too large they will crack the glass, and if too small will allow the filings to slip past.

When the coherer is placed so that the filings lie between the widest and the narrowest parts of the gap, they should occupy rather less than half its depth. The nickel is prepared for the simple coherer as described above.

Now, let us suppose that we substitute for the galvanometer some piece of apparatus which, like it, is actuated by the current flowing through the coherer. Let us also suppose that we provide the moving part of it with contacts suitably arranged to close a second circuit, through which we can send comparatively large currents. Such a piece of apparatus is called a relay, and enables us to actuate a bell, a Morse inker or sounder, or an automatic decohering device by means of currents of considerably greater strength than could be passed through the coherer itself. It is, in fact, a switch operated by small currents to which its moving part is very sensitive.

An ordinary moving-needle galvanometer would not make a satisfactory relay, more particularly as current must be led in through some kind of conducting wire or metallic suspension to the moving part which carries the contact.

A Simple Relay.—A very cheap and simple relay may be made from an old bell, the hammer-rod being removed and a light platinum-tipped contact piece being attached in its place.

A platinum-tipped contact screw must be so arranged that when the armature is drawn to the magnet the circuit is closed through the armature

spring and the two contacts; by screwing the contact in or out, the working distance between armature and magnet can be varied at will.

The motion of the armature is also regulated by an insulated screw used as a back-stop.

It is further advisable to provide means for varying the force exerted by the spring.

A relay made as described above is a very rough piece of apparatus, though quite good enough for simple experiments about a room. As, however, it is the author's intention to give a detailed description of a far more sensitive, yet fairly easily constructed, instrument, the above account has been made very brief and fuller directions must be sought elsewhere.

Second-hand Relays.—Fairly good second-hand relays may be picked up for prices varying from 2s. or 3s. to 6s. or 8s., according to quality and condition, but much larger sums are usually asked for the more sensitive Siemens *polarised* relay.

Requirements of a Relay.—For really good work the chief requirements of a relay are that it shall be very sensitive and have a very high resistance. The sensitiveness depends on the design of its electromagnetic system and on the mechanical perfection of the pivoting. Thus, what is known as a polarised relay is electrically far more sensitive than the simple armature and electro-magnet described above. The high resistance is necessary, because a fine and sensitive coherer gradually deteriorates, unless only very small currents are passed through it. The resistance should be at least 1,000 ohms, preferably 2,000 or 3,000 ohms. A second-hand relay often has a low resistance, in which case it

should be rewound with Nos. 38, 40, or even 42, copper, according to the size of the bobbins.

Construction of a Polarised Relay.—The following is a description of a very sensitive and satisfactory polarised relay of the Siemens type, designed and

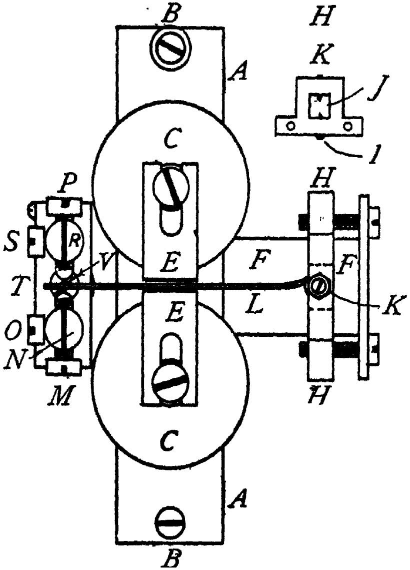


FIG. 43.—Plan of Polarised Relay.

made by Mr. Tolchard, of Paignton, South Devon. This instrument, which, by Mr. Tolchard's kind permission, the author has drawn and measured, presents no difficulties of construction and could not be much simplified; at the same time, it is

greatly superior to the ordinary attracted armature forms.

Fig. 43 is a plan, and Fig. 44 is a side elevation (full size) of the relay, which is constructed as follows :

A is a soft iron yoke, drilled at the ends to take the screws B, which hold it to the wooden base D.

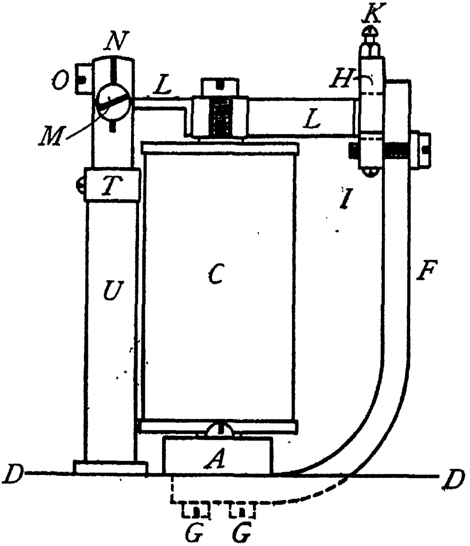


FIG. 44.—Elevation of Polarised Relay.

The cores of the electro-magnet C C are screwed into the iron A, and are drilled and tapped at the top, so as to take screws for holding the slotted pole-pieces E ; cores, yoke, and pole-pieces must all be of the softest iron procurable. The bobbins,

which are turned out of wood (preferably box), should be as thin as is compatible with strength. They are best wound in a lathe, though a hand-winding arrangement can easily be made ; the wire, No. 40 or No. 42 silk-covered, must be wound very carefully in even layers without kinks or abrasions, and any joints soldered and carefully insulated.

When both coils have been wound, the ends are soldered to pieces of No. 22 copper wire, which are secured to the bobbins, so that no mechanical strain is put upon the fine wire. Finally, the coils are soaked in melted paraffin wax, hot enough to drive the air and moisture out, but not hot enough to smoke. In this they are left until no more bubbles come out, when the wax is allowed to cool, the coils remaining in it. When the wax shows signs of congealing, the coils are taken out and stood aside to harden, as, by this time, they will have absorbed as much wax as possible.

The superfluous wax having been removed, the coils are covered with thin ebonite, suitably coloured paper, or cloth ; they are then forced on to the cores and connected in series, so that the current circulates round them in opposite directions in the usual way.

More detailed directions as to the winding of coils can be found elsewhere if required.

F is a strip of hard steel bent round and under the yoke A, to which it is held by the screws G G. The wooden base D D is cut away, so that A can be screwed down without F getting in the way.

When the steel F has been bent and the holes drilled for the screws G, F is hardened by heating it to a cherry red and plunging it into water, or, much better, into concentrated sulphuric acid or mercury :

mercury is best, and if sulphuric acid is used, it must be really concentrated, and great care must be taken to avoid splashing. In either case, a considerable quantity is required.

After hardening, F must be magnetised, longitudinally, as strongly as possible. This may be done by winding round it a temporary coil of three or four layers, and passing a very heavy current through the coil, while at the same time the ends of the steel are magnetically connected by an iron yoke. Another method is to place the steel lengthwise between the poles of a very powerful electro-magnet.

In either case, the magnetisation is helped by giving the steel a series of sharp blows with a piece of brass while it is in the magnetic field; the blows must not be too heavy as the hardened steel is very brittle. Failing these methods, magnetisation may be effected by any of the other ways given in text-books.

After magnetisation, the steel must be handled carefully and not knocked nor dropped.

H is a piece of brass which is cut to the shape shown separately (half size), and is pierced by the square hole J shown dotted in the drawings; through the bottom of H a small steel screw I passes and projects slightly into the square hole; its tip is coned and sharpened to a fine pivot-point, after which it is hardened. A second screw K, similarly made, passes through the top of H, and is provided with a locknut.

L is a thin light strip of soft iron, which is pivoted between I and K, and extends outwards between the pole-pieces E E; it is continued beyond E, but is partly cut away, the projecting portion being merely to carry a contact.

The end near F is riveted to a small block of steel, drilled on the top and underneath with pivot sockets, so that it lies in the square hole J, and can be pivoted between I and K.

K must be adjusted so that L cannot shake, but there must be the least friction possible. The gap between the block and the magnetised steel F should be small. At its other extremity, L carries a small piece of platinum, which is riveted or soldered to it.

M is a platinum-tipped contact screw, which passes through the split brass pillar N, and emerges opposite to the platinum contact piece on L.

O is a screw which passes freely through one-half of the split pillar, but screws into the further half, so that the two halves can be drawn together and made to lock the contact screw M.

The screw P is held in exactly the same way, but is provided with a small tip of ivory instead of platinum, and merely serves as a stop to adjust the position of L.

The pillars R and N are screwed into a brass plate T, held by a screw V to a brass pillar U.

The pillar U is shouldered and threaded at the lower end, where it passes through a hole in D D and is secured by a nut, for which a recess is provided on the under side of the base.

The wires from the relay magnet go to a pair of terminals, another pair being connected to the yoke A and to the pillar N. As this necessitates the passage of current through the pivots, it is advisable to provide a long spiral of the finest wire, making an extremely flexible connection between H and L; the wire may be soldered or secured by very small screws.

The action and adjustment of this relay are as follows :—

F is a powerful permanent magnet, the field from which passes up the cores of the electro-magnet C and across the gap between E and E to the soft iron tongue L, along which it flows to the pivot block, where it passes across to the top end of F.

Thus the pole-pieces E E are of the *same* polarity by induction from F, and they induce *opposite* polarity in the tongue L, where it lies between them. In this condition, L is said to be inductively polarised. If the travel of L is limited to a very small distance by the screws M and P, the slotted pole-pieces E E can be so adjusted by sliding them in or out that they exert almost exactly equal and opposite pulls on the tongue. As, however, a slight control is desired, E E are adjusted so that the tongue is held against the ivory stop with the smallest possible force. If now a very small current is passed through the coils, the balance of the induced magnetism is disturbed, the pull of one pole-piece being increased while that of the other is diminished.

A moment's consideration will show that if the current flows in one direction the tongue will only press harder against the ivory, whereas if the direction of flow is reversed and if the current is sufficient, the slight initial pull will be annulled, the tongue drawn over towards the other pole, and contact established between the platinum tips. The change of force produced by this disturbance of balance is far greater than the change of attractive force between an electro-magnet and an armature, if, as is likely, the former already has residual magnetism in its cores ; this is the reason for the great

increase of sensitiveness obtained by using a polarised instead of an unpolarised relay.

A Simple Receiver.—Fig. 45 shows the arrangement of a very simple and satisfactory receiver for ringing a bell about a house or across a lecture-room by Hertzian waves.

An ordinary electric bell is mounted on a vertical

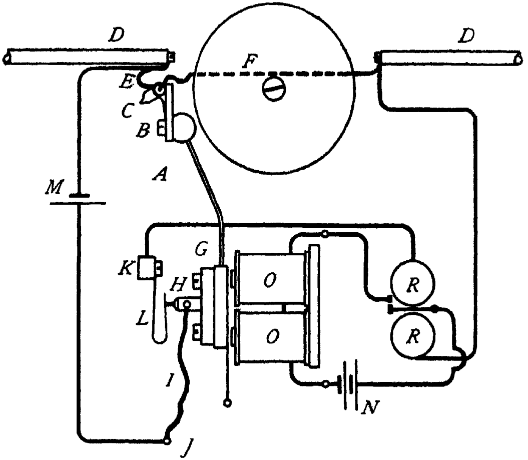


Fig. 45.—Mr. J. D. Coales' Receiver.

board, which rises from a wooden base. Behind the board there are three dry cells—one for the coherer-circuit and two for the bell-circuit. These rest on the base, and are secured to the vertical board by brass strips, or bridge-pieces, held by screws. Screwed down to the portion of the base in front of the board is the relay.

A flat is filed on the bell-hammer, and to it is screwed or soldered the brass plate A which carries the clip B of springy brass. Between the clip and the plate the coherer C is held firmly, and two fine wires E F lead from it to a pair of rods D D 2 or 3 ft. in length, which are held in drilled ebonite blocks fixed on to the vertical board. The coherer is shown in end view in the diagram, but the wires E F go to its opposite ends.

The contact arrangements of the bell are completely removed, and a strip of ebonite G is attached to the armature by screws. Into the ebonite a small brass pillar H tipped with platinum is screwed, so that it is well insulated from the armature. To this is soldered a short length I of flexible wire, leading to a terminal J.

K is a brass block mounted on ebonite and secured to the base of the bell; to it is fastened a flexible spring of brass L, which carries a platinum contact arranged to meet the one with which it is tipped.

The circuit of the cell M comprises the coherer (to which connection is made by wires leading to the rods D D), the coils R R of the relay, and the platinum contacts H and L.

The contacts of the relay are connected in series with the battery N and the coils O O of the bell. When waves fall on the rods D D and cause coherence, a current flows from M through the circuit M C R K L H J, the relay tongue is deflected, and the circuit of the battery N is closed. The bell magnet is then energised by the current from N and the armature is attracted, a blow being delivered to the gong of the bell; at the same time this blow shakes up the coherer and restores it to an insulating condition.

The contact L H is so adjusted that it breaks the coherer-circuit just before the hammer strikes the bell; before contact is re-made, the relay releases the tongue and breaks the circuit of the bell magnet. Thus—if matters are properly arranged—de-coherence takes place *after* the bell-magnet circuit is broken and *with* the coherer circuit open.

By this simple device the troublesome induction effects of sparks at relay and bell contacts are eliminated. (See page 127.)

It is obvious that by a slight modification the simple coherer described above could be equally well used with this receiver.

This receiver responds with great precision and crispness to single sparks recurring at intervals, but gives a rather irregular chatter in response to torrents of sparks produced by a coil fitted with a trembler.

The photograph reproduced in the frontispiece shows this receiver on the right in front of the Hertz oscillator plate.

The single sharp decisive stroke obtained when a jar discharges near the receiver is very effective, and the bell may be rung from one room to another by presenting a charged Leyden jar or an electrophorus to brass door-knobs, etc.

A well-charged jar may be presented several times to partially insulated objects such as these before it wholly loses its charge.

It is curious to hear the bell give a stroke every time a spark passes between the knobs of a Wimshurst machine working near at hand. There are other methods of decoherence without the use of separate tappers. One is to attach to the bell hammer a

short length of finely threaded rod or wire, which rests lightly on some sharp edge of the coherer attachment. When the hammer strikes, the screw-threads are dragged over the coherer attachment and decohere it very effectively.

Another method of decoherence is by the back stroke of the bell, in which case the bell coils and relay contacts must be provided with non-inductive shunts, as described on page 127.

A Complete Filings Tube Receiver.—Fig. 46 is from a photograph of a complete filings-tube receiver, the diagram of connections being as shown in Fig. 47; the same lettering is used in both illustrations. The filings-tube coherer C is connected to the terminals T_1, which are provided with brass blocks B B; these are drilled and tapped so that brass receiving rods threaded at the ends can be pushed through the drilled ebonite supports E E and screwed into the blocks.

The coherer is supported loosely by the ebonite blocks D D, which are drilled to a depth of about $\frac{1}{4}$ in. to take the ends of the coherer. Very fine holes are also drilled through in continuation of the former, and through these pass the thin wires (No. 36 copper) by which the coherer is connected to the terminals T_1. The blocks are seen more clearly in the photograph (Fig. 48). Mr. Tolchard, whose name has already been mentioned, finds that better results can be obtained with a firmly fixed coherer; but of this more must be said later.

From one of the terminals T_1 a wire goes to the two-way switch S_1, and from the other to the choking coil L_1, and one of the terminals T_2. From the other terminal T_2 a wire goes to the second contact of S_1,

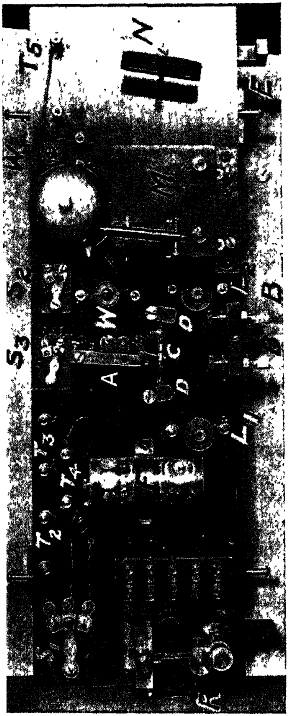


Fig. 46.—A Filings Tube Receiver.

the arm of S_1 being connected to the second choking coil L_2. The terminals T. were used for making the bell ring by the action of a separate coherer which was connected to them, and was substituted for the coherer C in the relay circuit by changing over the switch S_1 to the right. The arrangement was used in lectures for showing the behaviour of a coherer which was held in the hand and restored simply by tapping it with the finger; it is merely an added convenience, and if not required can be

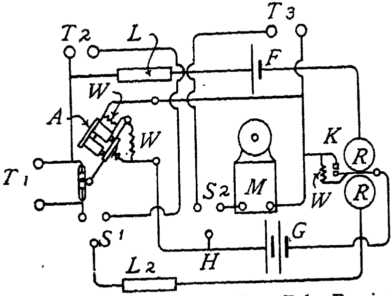


FIG. 47.—Connections of a Filings Tube Receiver.

omitted, in which case each of the terminals T_1 is connected straight to one of the choking coils L_1 L_2. These coils were introduced by Mr. Marconi for the purpose of preventing the oscillatory currents from being frittered away or interfered with by the capacity effects of the cell or relay. Their self-induction is sufficiently high to confine the oscillatory effects to the coherer, but their resistance is not enough to interfere with the currents which pass through the relay and coherer from the cell.

A hundred or more turns of No. 26 wire neatly wound on a bobbin is all that is required, an iron core being worse than useless. (See page 13.) The circuit of the coherer and the coils L L, is completed by the dry cell F and the coils R R of the relay.

The dry cell F is held down by a strip of brass screwed to the board on either side. The terminals T_4 are merely for convenience in connecting it.

The relay contact K closes the circuit of the

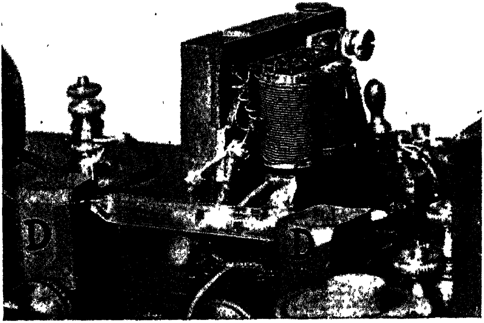


FIG. 48.—Filings Coherer and Tapper.

battery G, and this divides at the point H, going in one direction through the tapper A and in the other through the switch S_2, by means of which either the bell M or the terminals T_3 can be inserted. Thus for ringing up, the switch is turned to the right, the bell being then in parallel with the tapper, and both being fed by the battery G through the contact K. If the switch is turned to the left, the terminals T_3 are substituted for the bell, and a suitable Morse

sounder or inker connected to them will be actuated. The two dry cells forming the battery G are not shown in the photograph; they were held down by the wooden bridge-piece N, through the centre of which a screw was driven into the baseboard. The terminals T_5 are for convenience in connecting up the battery G. The single-way switch S_3 (not shown in the diagram) is merely for closing or breaking the circuit of G. The coils of the tapper and bell were shunted by non-inductive resistances. These are for the same purpose, and are wound in the same way as those described on page 127.

Shunts of considerably greater resistance, say 10 or 20 yards of No. 42 Eureka, should also be connected across the contacts of the relay, bell, and tapper.

Any apparatus used instead of the bell, such as a sounder or inker, must also be shunted.

The various shunts W, except those of the bell, are shown in the diagram, though only two are visible in the photograph.

The Tapper.—This is merely an electric bell with the gong removed, and the hammer so placed as to strike the coherer, as shown in the photograph, Fig. 48.

Some difficulty has been experienced in getting readable signals with the tapper illustrated, as there is serious mechanical and electrical interaction between the relay tongue and the armatures of the sounder and tapper — all of which have different periods of mechanical vibration. This causes the sounder or inker armature to rattle instead of remaining down during the passage of a torrent of sparks forming a Morse dash, and is largely due to the fact that the tapper was made from a very

small electric bell; the probabilities are that a larger bell with a slower period of stroke would not have given the same trouble.

The author's attention having been turned largely to the Lodge-Muirhead apparatus, he has not investigated this point further, but Mr. Tolchard finds that extremely crisp and rapid signalling can be obtained by using a simple receiver of his own design, which he has kindly lent for examination. The coherer is not precisely of the usual type, but apparently the essential point is its rigid fixture. The range of travel of the relay tongue is also made extremely small.

Very satisfactory decoherence can be effected continuously by clockwork in the manner adopted with such great success by Sir Oliver Lodge and Dr. Muirhead before they invented the wheel coherer.

Telegraphic Instruments.—Morse sounders or inkers may be used with the receiver, but no detailed account of them can be given here. A description of an easily constructed sounder appeared in *The Model Engineer* of July 13, 1905. It is as well, however, to point out that in order to avoid the mechanical interaction described above, the armature should be rather heavy and the controlling spring very weak, so that it may not jump every time the tapper momentarily causes decoherence.

An Automatic Switch.—There is only one feature in the filings-tube receiver remaining to be described: this is an automatic switch actuated by the bell, and used like the separate mercury switch described on page 131 for blowing fuses, etc.

The arrangement shows in Fig. 46, but is seen better in the photograph, Fig. 49.

A is a rod of brass, provided with a steel pin, turning in small brass bearings; these are screwed to a wooden block, which is fastened to the cover of the bell. A brass strip F is held to the end of the rod by a screw C, and terminates at its lower end in a toe.

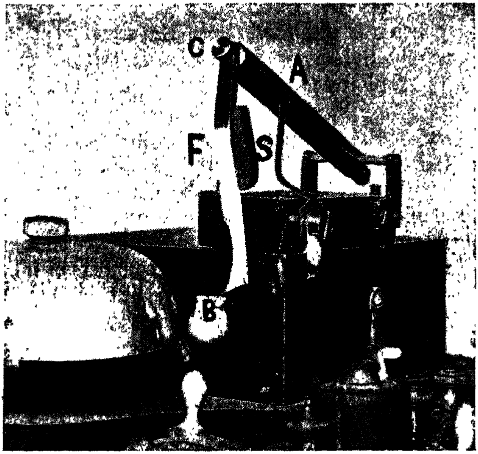


FIG. 49.—Automatic Switch. operated by Bell.

A small horizontal piece of brass B is soldered to the knob of the bell, and F is placed at such an angle (by turning it under the screw C) that the toe just rests on the edge of B.

If this arrangement is properly adjusted, the receiver can be a good deal shaken without the toe slipping off, but directly the bell-hammer strikes

the gong, B slips from under F, which falls and makes contact between the flexible brass switch-springs S; these are connected to a pair of terminals mounted on the bell-cover and just visible behind the wooden switch-block.

"AUTO-COHERERS."

Certain materials when used in coherers are self-restoring; that is, their resistance falls under the influence of waves and rises again on their cessation, without the necessity of automatic tapping devices. Such detectors are known, somewhat unsuitably, as auto-coherers.

They seldom have the high initial resistance of a filings-tube, and therefore they take some current as long as they are connected to a cell, though its value is increased on the arrival of waves; also, the restoration of the resistance to the higher value when the waves cease is extremely rapid. For these reasons they are not suitable for use with a relay, and are usually connected in circuit with a cell and telephone. Each spark is accompanied by a slight tick in the telephone, so that a dash is heard as a long buzz or crackle, and a dot as a short one. The simplest auto-coherer is made by bridging across a pair of carbon blocks with one or two steel needles, the whole apparatus being arranged so that it can be tilted at various angles to alter the pressure between needles and carbon.

The Castelli Coherer.—Perhaps the best and most sensitive auto-coherer is that invented by Paolo Castelli, a signalman in the Italian Navy. It consists simply of a glass tube containing a globule of mercury between two plugs, which may be both of iron, or,

preferably, one of iron and one of carbon. Fig. 50 shows diagrams, A of this coherer, and B of an alternative form in which two globules are used between a central plug of iron and two outer plugs of carbon.

The electrodes of iron should be free from oxide and well polished at the ends; the inside of the tube should be perfectly clean, and the mercury pure. The internal diameter of the tube should be about 3 mm., and the size of the drop from 1½ to 2½ mm. If the drop is of less diameter than 1½ mm., the coherer is insensitive. If larger than 2½ or 3 mm., the action is not sufficiently sharp and crisp. The

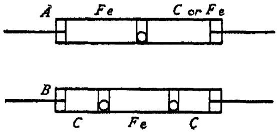


FIG. 50.—Two forms of Castelli Coherer.

distance between the electrodes is very important, and requires careful adjustment by experiment.

The connections of the circuit are shown in Fig. 51; they are exactly the same as those for the filings coherer shown on page 135, except that a telephone is used instead of a galvanometer.

A Leclanché or dry cell should be used, and sometimes the coherer works better with a cell which is slightly run down.

Captain Bonomo gives the following as a good preliminary adjustment:—

The tube is held in the hand and inclined at an angle of about 35 degs. or 40 degs. to the horizontal.

The upper electrode is then displaced until the visible space between it and the drop is from ·2 to ·5 mm. Finally, the distance is adjusted while the operator listens at the telephone.

Tubes in which the decoherence is imperfect cause a sound in the telephone "like oil frying in a distant frying-pan"; in such a case it is sufficient to move one electrode outwards about $\frac{1}{10}$ mm. It is advisable to provide a fine screw adjustment for varying the distance. Sometimes a light tap will stop the frying sound.

In certain cases, Captain Bonomo found it advantageous to roll the drop of mercury in fine clean

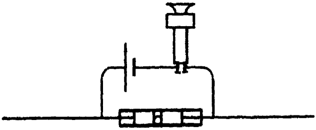


FIG. 51.—Circuit for Castelli Coherer.

dust from an arc-lamp carbon, so as to coat it with a very thin film.

AN "ELECTROLYTIC" DETECTOR.

An extremely simple detector was discovered some years ago by Prof. Neugschwender, and has been called an anti-coherer because its resistance *increases* under the influence of Hertzian waves.

A piece of silvered glass about ½ in. wide is cut and mounted in some way which enables connection to be easily made with the two ends of the silver coating. A fairly sharp knife is then drawn firmly across the silver from one side to the other, so as to divide it in halves. If there is any doubt as to

whether it has been completely divided, the passage of a current will soon burn away any fragment bridging the gap. The completed detector is provided with extension wires and inserted in circuit with a cell and galvanometer.

If the gap be breathed upon, the galvanometer deflects, because the moisture has condensed in the gap, and fine bridges, or electrolytic trees of metallic silver have been formed between its edges.

Directly Hertzian waves fall upon the extension wires, an oscillatory current is induced and rushes across the gap, dispersing and breaking up the electrolytic trees and causing a great increase of resistance and decrease of galvanometer deflection. On the cessation of the waves, the particles of silver join up again and arrange themselves end to end, reforming the bridges, restoring conductivity, and preparing the detector for the next signal.

It is very interesting to watch these effects through a microscope, while listening at the same time to a telephone inserted in circuit in place of the galvanometer. At the moment of switching on the current, a furious bubbling and scraping noise is heard while the conducting bridges are forming. This is followed by silence, which is practically unbroken except for the click heard each time a spark occurs at the transmitter; these effects have been very graphically described by Dr. Lee de Forest. A telephone can be used with this detector much as it is used with the Castelli coherer.

As the moisture dries rather rapidly, and it is tiresome to have to breathe on the detector at intervals, a piece of wet cotton wool may be placed near to, but not in contact with the gap.

APPENDIX.

The Morse Alphabet and Its Use.

Signalling is accomplished by sending long or short groups of wave-trains in certain recognised sequence, the arrangement being different for each letter of the alphabet.

A momentary depression of the signalling key constitutes a dot, and this consists of a short group of sparks, each of which sends out a train of waves to the distant receiver; if the key is held down for longer, a dash or long group of wave-trains is produced.

Each letter or other sign is made up of dots and dashes, and the letters are distinguished from each other by longer periods of rest than those given between the signals which make up the letter.

The beginner is advised to transmit various letters in continuous repetition for three or four minutes each, until the person at the receiving end is thoroughly used to reading them.

V is a clear and useful letter to send while adjustments are being made at the receiving station.

Until the operators are thoroughly familiar with the different signals, it is well for all messages to be written on a piece of paper in the Morse code and transmitted while the sender reads from this paper.

Similarly, the receiving operator should write down, in properly spaced dots and dashes, all that he receives, interpreting it at leisure when the signals have ceased.

Any hesitation while the signals for letters are hunted for in a book will lead to hopeless confusion, and spontaneous messages sent as they come to mind should not be attempted until thorough proficiency has been attained.

Dots should be sharp and crisp, and dashes should be long enough to give them clear distinction.

Uniformity of dots, dashes, and spacings should be aimed at; but signals should be sent slowly at first, the speed being increased as the code becomes familiar.

The Morse code is as follows:—

A - —	J - — — —	S - - -
B — - - -	K — - —	T —
C — - — -	L - — - -	U - - —
D — - -	M — —	V - - - —
E -	N — -	W - — —
F - - — -	O — — —	X — - - —
G — — -	P - — — -	Y — - — —
H - - - -	Q — — - —	Z — — - -
I - -	R - — -	Full stop - - - -

Repetition - - — — - -   Hyphen — - - - - —

Apostrophe - — — — — -

HAMPTON AND CO., PRINTERS, 12-13, CURSITOR STREET, LONDON, E.C.

LIST OF

Technical Books

SUPPLIED BY

Percival Marshall & Co.,

27L, POPPIN'S COURT, FLEET STREET, LONDON, E.C.

Any Technical Book not in this List can be supplied to order. Inquiries are invited, and will be answered by post free of charge. Foreign and Colonial customers please note that the postages given, unless stated, are for Great Britain, and extra money should be sent to cover the higher postage for Colonies and Foreign Countries.

MECHANICAL ENGINEERING.

Gas and Oil Engines, and Gas Fitting.

A Practical Treatise on Modern Gas and Oil Engines. By Fred. Grover, A.M.Inst.C.E. Third Edition. Illustrated. With 372 pages. Postage 4d. ... ... 5s. 0d.

Acetylene: The Principles of its Generation and Use. By F. H. Leeds, F.I.C., F.C.S., and W. J. Atkinson Butterfield, M.A., F.I.C., F.C.S. With Diagrams and Illustrations. Postage 4d. ... ... 5s. 0d.

Gas Fitting. By W. Grafton. With 143 Illustrations, 8vo. Postage 4d. 5s. 0d.

The Gas Engine Manual. By W. A. Tookey. A well illustrated and practical Handbook for Gas Engine Users. Postage 4d. ... ... 3s. 6d.

Gas and Petroleum Engines. Adapted from the French of H. De Graffigny, by A. G. Elliott, B.Sc. A Useful and Elementary Treatise for Non-Technical Readers. With 52 Illustrations. Postage 3d. ... ... 2s. 6d.

Practical Gas Fitting. By Paul N. Hasluck. With 120 illustrations, 160 Pages. Cloth. Crown 8vo. Postage 3d. ... ... 2s. 0d.

Gas Engines: Their Advantages, Action, and Application. By W. A. Tookey. Hints to Purchasers, Erectors, and Attendants. Postage 2d. 1s. 0d.

Oil Engines: Their Selection, Erection and Correction. By W. A. Tookey. Hints to Purchasers Erectors and Attendants. Postage 2d. 1s. 0d.

Gas Producers for Power Purposes. By W. A. Tookey. For the use of Purchasers, Erectors and Attendants. Postage 2½d. ... ... 1s. 0d.

Working Hints for Suction Gas Producers. By A. Flurscheim. Postage 1d. ... ... 1s. 0d.

Gas and Oil Engines. Simply explained. By W. C. Runciman. An Elementary Instruction Book for Amateurs and Engine Attendants. Fully Illustrated. Postage 1d. ... ... 6d.

Acetylene Gas: How to Make and Use it. By Cyril N. Turner. A Practical Handbook on the Construction and Working of Small Lighting Plants. Fully illustrated. Postage 1d. ... ... 6d.

General Engineering.

A Text Book of Mechanical Engineering. By Wilfrid J. Lineham, M.Inst.C.E., M.I.Mech.E., M.I.E.E. Contains 1,000 pages, with 920 Illustrations and 19 Folding Plates. Postage 6d. ... ... 12s. 6d.

Mechanical Movements, Powers, Devices, and Appliances. By Gardener D. Hiscox. For the use of Inventors, Mechanics, Engineers, Draughtsmen, and all others interested in any way in Mechanics. Illustrated by 1,649 Engravings. 402 pages. 8vo. Cloth. Postage 5d. ... ... 12s. 6d.

Engineer's Sketchbook of Mechanical Movements, Devices, Appliances, etc. For use in the Design and Construction of Machinery. By T. W. Barber, M.Inst.C.E. Fifth Edition. 3000 Illustrations. Postage 5d. 10s. 6d.

The Repair and Maintenance of Machinery. By T. W. Barber. With 417 Illustrations. 8vo. Postage 5d. ... ... 10s. 6d.

Mechanical Refrigeration. By Hal Williams, A.M.I.E., A.M.I.E.E. With 115 Illustrations. Crown 8vo. Postage 4d. ... ... 10s. 6d.

An Advanced Text Book on Applied Mechanics. By Professor Jamieson.
Vol. 1. Comprising Part 1: The Principle of Work and its applications; Part 2: Gearing. Third Edition. Postage 5d. ... ... 7s. 6d.
Vol. 2. Comprising Parts 3—6: Motion and Energy; Graphic Statics; Strength of Materials; Hydraulics and Hydraulic Machinery. Second Edition. Postage 5d. ... ... 12s. 6d.

Toothed Gearing. By J. Horner, A.M.I.M.E. A Practical Handbook for Offices and Workshops. With 184 Illustrations. Crown 8vo. Cloth. Postage 4d. ... ... 6s. 0d.

Steel and Iron. By Prof. W. H. Greenwood, F.C.S., M.I.C.E. A Technical Handbook. With about 100 diagrams. Postage 4d. ... ... 5s. 0d.

The Chemistry of Materials of Engineering. By A. Humboldt Sexton. Crown 8vo. Postage 4d. ... ... 5s. 0d.

Practical Notes on the Construction of Cranes and Lifting Machinery. By Edward C. R. Marks, A.M.I.C.E., M.I.M.E. New and Enlarged Edition. Crown 8vo. Postage 3d. ... ... 4s. 6d.

Elementary Manual of Applied Mechanics. By Prof. Jamieson. Specially arranged for First Year Students. Fifth Edition. With Illustrations and Examination Papers. Crown 8vo. Postage 3d. ... ... 3s. 6d.

Engineering Workshop Practice. By Charles C. Allen. This book is intended as a guide for Students and Engineering Workmen generally. Illustrated. Postage 4d. ... ... 3s. 6d.

The Strength of Materials and Structures. By Sir J. Anderson, C.E., LL.D., F.R.S.E. Showing the strength of materials as depending on their quality and as ascertained by testing apparatus. With 66 Illustrations. Fcp. 8vo. Postage 3d. ... ... 3s. 6d.

Mechanical Engineering Materials. By Edward C. R. Marks, A.M.I.C.E. M.I.M.E. Postage 3d. ... ... 2s. 6d.

Locomotives and Railways.

Modern Locomotive Practice. By C. E. Wolff, B.Sc., A.M.I.M.E. A treatise on the Design of Steam Locomotives. With 150 Illustrations and 8 folding Plates. Postage 4d. ... ... 10s. 6d.

British Locomotives. Their History, Construction, and Modern Development. By C. J. Bowen Cooke. With 150 illustrations. Third Edition. Thoroughly revised. Crown 8vo. Postage 4d. ... ... 7s. 6d.

The World's Locomotives. By C. S. Lake. A Digest of the Latest Locomotive Practice in the Railway Countries of the World. With 300 illustrations and 8 folding plates. Postage, Great Britain, 6d.; Foreign and Colonial, 1s. 3d. ... ... 10s. 6d.
Locomotives of 1906. By C. S. Lake. A Supplement to The World's Locomotives. Postage 3d. ... ... 1s. 0d.
Locomotives of 1907. By C. S. Lake. A Supplement to The World's Locomotives. Postage 3d. ... ... 1s. 0d.
The Model Locomotive: Its Design and Construction. By Henry Greenly. 274 pages. 370 Illustrations and 9 Plates. Demy 8vo. Postage 4d. ... ... 6s. 0d.
Locomotive Engine Driving. By Michael Reynolds. A Practical Manual for Engineers in charge of Locomotive Engines. Eleventh edition. Crown 8vo. Cloth. Postage 4d. ... ... 4s. 6d.
The Locomotive Engine and its Development. By Clement E. Stretton, C.E. A popular Treatise on the Gradual Improvements made in Railway Engines between 1803 and 1903. Sixth Edition. Revised and Enlarged. With 130 Illustrations. Crown 8vo. Cloth. Postage 4d. ... 4s. 6d.
Modern British Locomotives. By A. T. Taylor. 100 Diagrams and principal Dimensions. Postage 3d. ... ... 4s. 6d.
The Locomotives of the G.N.R. By George Frederick Bird. A Chronological account of the Locomotive Stock of the G.N.R. from its inception to the present day; every type illustrated and described. Postage 3d. 3s. 6d.
Locomotives of the L.B. & S.C.R. A complete history of all the locomotives of the L.B. & S.C.R. from 1839 to the present day. 144 illustrations from Drawings and Photographs, every engine illustrated and described. Postage 3d. ... ... 3s. 6d.
Railway Appliances. By Sir J. Wolfe Barry, K.C.B., F.R.S., etc. A Description of Railway Construction subsequent to the completion of the Earthworks and Structures. With 218 Illustrations. Fcp. 8vo. Postage 3d. 4s. 6d.
The Locomotive Portfolio. By F. Moore. Containing 12 beautifully executed Coloured Plates of Modern British Express Locomotives. Postage 4d. 3s. 6d.
The Locomotive of To-day. A thoroughly practical Treatise on the British Locomotive; every detail carefully illustrated and described. Post. 3d. 2s. 6d.
Railway Working and Appliances. By Edward S. Hadley. Describes the Methods and Mechanisms by which Railways in Great Britain are conducted. Illustrated. Postage 3d. ... ... 1s. 6d.
Railway Views. An Album containing Photo Engravings of Railway Subjects at Home and Abroad. Postage 2d. ... ... 1s. 0d.
Engine Driving Life. By Michael Reynolds. Stirring Adventures and Incidents in the lives of Locomotive Engine Drivers. Third Edition. Crown 8vo. Cloth. Postage 3d. ... ... 1s. 6d.
The Locomotive Simply Explained. By C. S. Lake. A First Introduction to the Study of the Locomotive Engine. Postage 1d. ... 6d.

Machine Design and Drawing.

The Elements of Machine Design. By W. Cawthorne Unwin, F.R.S.
Part I. General Principles, Fastenings, and Transmissive Machinery. With 345 Diagrams, etc. Postage 4d. ... ... 7s. 6d.
Part II. Chiefly on Engine Details. With 259 Illustrations. Postage 4d. ... ... 6s. 0d.
Mathematical Drawing Instruments and Materials. By A. G. Thornton. Describes all Instruments and Materials used in Drawing, Tracing, &c. Postage 4d. ... ... 3s. 6d.
Machine Drawing. By T. Jones, M.I.M.E., and T. G. Jones, M.Sc., Wh.Sc.
Book 1. Eleventh Edition. Enlarged. General Details of Engines and Machines. 58 Plates (four coloured). Postage 4d. ... 3s. 0d.
Book 2. Machine Tools. Drilling, Planing, Slotting, and Shaping. Second Edition. 48 Plates (four coloured). Postage 4d. ... 3s. 0d.
Book 3. Engine and Pump Details. Third Edition. 44 Plates (four coloured). Postage 3d. ... ... 3s. 0d.
The above three books, handsomely bound in one volume. Postage 6d. 10s. 6d.
Book 4. Electrical Machines and Details. 16 Plates. Postage 2d. 1s. 0d.

An Introduction to Machine Drawing and Design. By David Allan Low. With 153 Illustrations and Diagrams. Crown 8vo. Postage 3d. 2s. 6d.

Sketches of Engine and Machine Details. By Wallace Bentley, M.I.M.E. This book contains over 200 Detail Drawings, fully dimensioned, from the latest practice, and includes drawings from Stationary, Locomotive, and Marine Engines, Boilers, Gas and Oil Engines, Machine Tool, Electric Motors, etc. Fourth Edition, enlarged Postage 3d.... ... 2s. 6d.

Machine Shop Arithmetic. By Colvin. A Pocket Book containing Solutions to Problems met with by every mechanic. Postage 2d. ... 2s. 6d.

Engineering Mathematics Simply Explained. By H. H. Harrison. A Textbook for Apprentices, Students and Engineers. Postage 3d. 1s. 6d.

Engineer Draughtsmen's Work. By a Practical Draughtsman. Hints to Beginners in Drawing Offices. Second Edition. With 80 Illustrations. Postage 2d. ... ... 1s. 6d.

Mechanical Drawing Simply Explained. An Elementary Handbook on Engineering Draughtsmanship for Students, Apprentices and Amateurs. Fully Illustrated. Postage 1d. ... ... 6d.

Marine Engineering.

Text Book on Marine Motors. By Capt. E du Boulay. Postage 6d. 10s. 6d.

Wannan's Marine Engineer's Guide to Board of Trade Examinations for Certificates of Competency. By A. C. Wannan, C.E., and E. W. I. Wannan, M.I.M.E., Certificated 1st Class Marine Engineer. Containing all latest Questions to Date, with Simple, Clear, and Correct Solutions; 302 Elementary Questions with Illustrated Answers, and Verbal Questions and Answers; complete set of Drawings with Statements Completed. Large crown 8vo. Cloth. Postage 5d. ... ... 10s. 6d.

Verbal Notes and Sketches for Marine Engineers. Contains Notes and Sketches given at the Board of Trade Examination. By J. W. Sothern. Postage 4d.... ... ... 7s. 6d.

Drawing and Designing for Marine Engineers. By Chas. W. Roberts, M.I.Mar.E. With 27 Illustrations and 21 large Plates. Demy 8vo. Cloth gilt. Postage 4d. ... ... 6s. 0d.

Engine-room Practice. By John G. Liversidge, A.M.I.C.E., etc. A Handbook for Engineers and Officers in the Royal Navy and Mercantile Marine, including the Management of the Main and Auxiliary Engines on board ship. Third impression, with numerous Illustrations. Lrg. cr. 8vo. Postage 4d. 6s. 0d.

Elementary Lessons in Steam Machinery, and the Marine Steam Engine. By J. Langmaid, R.N., and H. Gaisford, R.N. With a Short Description of the Construction of a Battleship. Compiled for the Use of Junior Students of Marine Engineering. New Edition. 8vo. Postage 3d. ... ... 6s. 0d.

The Resistance and Power of Steamships. By W. H. Atherton, M.Sc., and A. L. Mellanby, M.Sc. Cloth. Postage 3d. ... ... 5s. 0d.

Marine Engineers: Their Qualifications and Duties. By E. G. Constantine, A.M.I.C.E., etc. With Notes on the Care and Management of Marine Engines, Boilers, and Machinery. Crown 8vo. Cloth. Postage 4d. ... 5s. 0d.

Practical Mechanics. By Thos. Mackenzie, F.R.A.S. Applied to the Requirements of the Sailor. Second Edition, revised. With numerous Illustrations. Postage 3d. ... ... 3s. 6d.

Practical Advice for Marine Engineers. By Chas. W. Roberts, M.I.Mar.E. With 64 Illustrations. Crown 8vo. Cloth. Postage 3d. ... 3s. 0d.

Model Making and Amateur Mechanics.

Practical Boat Sailing for Amateurs. By G. Christopher Davis. Second Edition. Revised and Enlarged, and with several new plans of Yachts. Containing particulars of the most suitable sailing boats and yachts for amateurs and Instructions for their proper handling, etc. Illustrated with numerous diagrams. Postage 4d. ... ... 5s. 0d.

Model Yachts and Boats. By J. Du V. Grosvenor. Giving their Designing, Making and Sailing. Illustrated with 118 designs and working diagrams. In Leatherette. Postage 3d. ... ... 2s. 6d.

Practical Boat Building for Amateurs. By Dixon Kemp. Second Edition, Revised and Enlarged, containing full instructions for Designing and Building Punts, Skiffs, Canoes and Sailing Boats, etc. Fully Illustrated with working diagrams. Postage 3d. ... ... 2s. 6d.

Amateur's Companion to the Workshop. Being a Collection of Practical Articles and Suggestions for the use of Amateur Workers, with some details as to construction of Electrical and other Models and Apparatus. Illustrated. Postage 3d.| ... ... 1s. 6d.

Model Steam Engine Design. By R. M. de Vignier. Illustrated. Postage 1½d. ... ... 1s. 6d.

Building Model Boats. By P. N. Hasluck. Illustrated. Postage 2d. 1s. 0d.

Repousse Work for Amateurs. By L. L. Haslope, showing the Art of Ornamenting thin Metal with Raised Figures. Illustrated. In Paper. Postage 2d ... . 1s. 0d.

Working in Sheet Metal. By the Rev. J. Lukin, B.A. Being practical instructions for making and mending small articles in tin, copper and iron, zinc and brass. Illustrated. Third Edition. In paper. Postage 1d. ... 1s. 0d.

Model Engineer's Handybook. By Paul N. Hasluck. A Practical Handbook on the Construction of Model Steam Engines. With upwards of 100 Illustrations. 144 pages. 8vo. Cloth. Postage 3d. ... ... 1s. 0d.

Model Sailing Yachts. How to Build, Rig, and Sail Them. Edited by Percival Marshall, A.I.Mech.E. A practical handbook for Model Yachtsmen. Illustrated. Postage 3d... ... ... 1s. 0d.

Simple Mechanical Working Models: How to make and use them. Edited by Percival Marshall, A.I.Mech.E. Gives Instructions for making Model Water Motors, Model Hot-air Engine, Cardboard Working Model Locomotives, Model Gravitation Railway, etc. Fully Illustrated. Postage 1d. 6d.

Machinery for Model Steamers. Edited by Percival Marshall, A.I.Mech.E. A Practical Handbook on the Design and Construction of Engines and Boilers for Model Steamers, the Use of Liquid Fuel, and the Proportions of Machinery for Model Boats. Fully Illustrated. Postage 1d. ... ... 6d.

Model Steamer Building. Edited by Percival Marshall, A.I.Mech.E. A Practical Handbook on the Design and Construction of Model Steamer Hulls and Fittings. Fully Illustrated. Postage 1d. ... ... 6d.

Model Steam Turbines: How to Design and Build Them. Fully Illustrated. Postage 1d. ... ... 6d.

Model Steam Engines: How to Understand Them and How to Use Them. Postage 1d. ... ... 6d.

Models for Engineering Students.

Working Models, ("X" Series), Prepared by T. & T. G. Jones.
Model No. 1. Complete in box, with book of Notes and short Essay on the Steam Engine. Postage 3d. 2s. 6d
Model No. 2. Complete in box, with book of Notes and short Essay on the Steam Engine. Postage 3d. ... ... 3s 0d.
Nos. 1 and 2. Complete in box, with Notes. Postage 3d ... 5s. 0d.

Working Models. By T. & T. G. Jones. Series 1 & 2 show at a glance the working of the various Types of Slide Valves used in modern Steam Engines. Eight Cardboard Models, in box with full explanations. Postage 2d. 2s. 6d.
Series 3. Comprising 6 Cardboard Models of modern High Speed Engines specially constructed for driving Dynamos. Complete in box, with full explanatory notes. Postage 3d.... ... ... 5s. 0d.

Descriptive Geometry Models. By Thomas Jones, Gold Medallist.
Series No. 1. Six Models with descriptive letterpress and 40 Problems for Solution. Postage 1d. ... ... 1s. 3d.
Series No. 2. Six Models with descriptive letterpress and 40 Problems for Solution. Postage 1d. ... ... 1s. 3d.
Series 1 and 2, in one volume. Postage 1½d. ... ... 2s 0d.

Motor Cars and Cycles.

The Encyclopædia of Motoring. Containing full definitions of every term used in motoring, with special articles on roadside troubles, etc Illustrated. Postage 4d. ... ... 7s. 6d.

Petrol Motors and Motor Cars. By T. Hyler White, A.M.I.M.E. A Handbook for Engineers' Designers and Draughtsmen. Cloth. Illustrated. Postage 3d. ... ... 4s. 6d.

Useful Hints and Tips for Automobilists. From *The Autocar.* 478 suggestions for repairs, &c. Postage 3d. ... ... 2s. 6d.

Motor Repairing for Amateurs. By John Henry Knight. 69 Illustrations Postage 2d. ... ... 2s. 6d.

Magnetos for Automobilists. How made and how used. By S. R. Bottone. Postage 3d.... ... ... 2s. 0d.

Ignition Devices. For Gas and Petrol Motors. By S. R. Bottone. A chapter treats specially of Structural Details, Choice and Management of Automobiles. Illustrated. Postage 3d. ... ... 2s. 6d.

Carburetters and Carburation. By Douglas Leechman. Many different types are explained and Illustrated. Postage 3d. ... ... 2s. 0d.

Motor Ignition Appliances. A practical treatise on the application of Electricity in the production of the Ignition Spark in Petrol Motors. By T. H. Hawley. Postage 3d. ... ... 1s. 6d.

Electric Ignition for Motor Vehicles. By W. Hibbert, A.M.I.E.E. Gives particulars of some systems, faults, &c. Illustrated. Postage 2d. 1s. 6d.

The Autocar Handbook. A Guide to the Motor Car. How to Select, Maintain and Drive an Automobile. Illustrated. Postage 3d. 1s. 6d.

The Motor Manual. A practical handbook dealing with the working principles, management, etc., of petrol cars. 160 illustrations. Postage 3d. 1s. 6d.

Systems of Electric Ignition for Motor Cars. By Douglas Leechman. 111 Illustrations. Describes many different types. Postage 3d. 1s. 6d.

Cycle Building and Repairing. Prepared under the direction of P. N. Hasluck. A Practical Manual, with 142 Illustrations. Cloth. Postage 2d. 1s. 0d.

Petrol Motors Simply Explained. By T. H. Hawley. Describes the principles on which Petrol Motors work, with hints on driving. Illustrated. Postage 3d. ... ... 1s. 0d.

"The Car" Encyclopædia of Component Parts, Motoring Definitions and Terms. Postage 2d. ... ... 1s. 0d.

Practical Motor Car Repairing. A Handbook for motor car owners and drivers. Illustrated. Postage 3d. ... ... 1s. 0d.

The Art of Driving a Motor Car. By Lord Montague. Postage 2d. 1s. 0d.

Motor Car Mechanics for Beginners. By G. Foster Pedley. Postage 2d. 1s. 0d.

The Care of the Car and How to Drive It. By Lord Montagu and R. J. Mecredy. Postage 2d. ... ... 1s. 0d.

Motor Cycles and How to Manage Them. Eleventh edition. Postage 2d. 1s. 0d.

Hints and Tips for Motor Cyclists. From "The Motor Cycle." 262 well indexed Hints and Tips. Postage 2d. ... ... 1s. 0d.

The Petrol Engine. Troubles and Remedies. By C. W. Brown. Postage 2d. 1s. 0d.

Popular Books on Engineering and Science.

The Conquest of the Air. By John Alexander. The Romance of Aërial Navigation. With Preface by Sir Hiram S. Maxim. Illustrated. 160 pages. Handsome cloth cover. Crown 8vo. Postage 3d. ... ... 1s. 6d.

Simple Scientific Experiments. By Aurel De Ratti. Describes Forty-six instructive Experiments in Electricity, Magnetism, Hydraulics, Hydrostatics, Light, and Acoustics. Fully Illustrated. Postage 1d. ... 6d.

Pumps and Hydraulic Engineering.

Practical Handbook on Pump Construction. By P. R. Björling. Second Edition. 9 Plates. Crown 8vo. Postage 4d. ... ... 5s. 0d.

Steam Engineering.

The Steam Turbine. By Robert M. Neilson, Wh. Ex., A.M.I.M.E. With 145 Illustrations. 8vo. Postage 4d. 15s. 0d

A Text Book on Steam and Steam Engines. By Prof. Jamieson, For the Use of Students Preparing for Competitive Examinations. With 600 pages. Over 200 Illustrations, 6 folding Plates, and numerous Examination Papers. Fourteenth Edition. Revised. Postage 4d. ... 10s. 6d.

Steam Engine Theory and Practice. By W. Ripper. With 438 Illustrations. 8vo. Postage 4d. ... ... 9s. 0d.

The Marine Steam Turbine. A practical description of the Parson's Marine Turbine. 60 illustrations. Postage 4d. ... ... 12s. 6d.

Steam Boilers. By R. D. Munro. Showing their Defects, Management, and Construction. Fourth Edition. Fully Illustrated. Postage 3d. 4s. 6d.

Steam Engineering. By W. W. F. Pullen, Wh. Sc., M.I.M.E., A.M.I.C.E. A Treatise on Boilers, Steam, Gas and Oil Engines, and Supplementary Machinery, with Instructions for Carrying out numerous experiments. 350 pages. 300 Illustrations. Postage 5d. ... ... 4s. 0d.

Stationary Engine Driving. By Michael Reynolds. A Practical Manual for Engineers in Charge of Stationary Engines. With Plates and Woodcuts. Sixth Edition. 8vo. Cloth. Postage 3d. ... ... 3s. 6d.

Elementary Manual of Steam and the Steam Engine. By Prof. Jamieson. For First year Students. Ninth Edition. Revised. With Illustrations and Examination Papers. Postage 3d. ... ... 3s 6d.

Injectors: Theory, Construction, and Working. By W. F. Pullen, Wh. Sc., A.M.I.C.E. Second Edition. Revised and Enlarged. Crown 8vo. Postage 3d. ... ... 3s. 6d.

A Handbook for Steam Users. By M. Powis Bale, M.I.M.E., A.M.I.C.E. Giving Rules for Engine Drivers and Boiler Attendants, with Notes on Steam Engine and Boiler Management, and Steam Boiler Explosions. Fcp. 8vo. Postage 3d. ... ... 3s. 6d.

The Compound Engine. By William J. Tennant, A.M.I.Mech.E. An elementary treatise on the working of Compound Engines. Crown 8vo. Cloth. Postage 3d. ... ... 2s. 6d.

Steam. By W. Ripper. With 185 Illustrations. Postage 3d. ... 2s. 6d.

The Theory of the Steam Turbine. By H. M. Martin, Wh.Sc. and R. H. Parsons, A.M.I.C.E. Illustrated. Postage 2d. ... ... 1s. 6d.

The Working of Steam Boilers. By Edward G. Hiller. Postage 2d. 1s. 0d.
Ditto ditto ditto Cloth. Postage 3d. 1s. 6d.

The Care and Management of Stationary Engines. By C. Hurst. A Practical Handbook for Men-in-Charge. Crown 8vo. Cloth. Postage 3d. 1s. 0d.

Model Steam Engines: How to Understand Them and How to Run Them. By Henry Greenly. Fully Illustrated. Postage 1d. ... 6d.

Model Boiler Making. By E. L. Pearce. A Practical Handbook on the Designing, Making and Testing of Small Steam Boilers. Fully Illustrated with Original Working Drawings. Postage 1½d. ... ... 6d.

The Slide Valve Simply Explained. By W. J. Tennant, A.M.I.Mech.E. Gives a clear and simple explanation of the Working of the Steam Engine Slide Valve. With 36 Illustrations. Postage 1d. ... ... 6d.

Workshop Tools and Processes.

Metal Plate Work: Its Patterns and their Geometry, for the Use of Tin, Iron, and Zinc Plate Workers. By C. T. Millis. Fourth Edition. 280 Diagrams. 470 pages. Crown 8vo. Postage 4d. ... ... 9s. 0d.

Pattern Making. By Joseph Horner, A.M.I.M.E. Third Edition. Enlarged. With 486 Illustrations. A Practical Treatise embracing the Main Types of Engineering Construction, including Gearing, Sheave, and Pulleys, Screws, Machine Parts, Pumps, Estimating the Weight of Castings, etc., etc., etc. Crown 8vo. Postage 4d. 7s. 6d.

Metal Working Tools and their Uses. By Percival Marshall, A.I.M.E. A Practical Handbook for Young Engineers and Amateur Mechanics. Showing how to use Simple Tools required in Metal Working and Model Making. Fully Illustrated. Second Edition. Postage 1d. ... 6d.

The Beginners' Guide to the Lathe. By Percival Marshall, A.I.Mech.E. An Elementary Instruction Book on Turning in Wood and Metal. Postage 1d. ... ... 6d.

A Guide to Standard Screw Threads and Twist Drills (Small Sizes). By George Gentry. Postage 1½d. ... ... 6d.

ELECTRICAL ENGINEERING.

Dynamos and Motors.

Design of Dynamos (Continuous Current Generators). By Silvanus P. Thompson. 92 Illustrations and 8 folding plates. Postage 6d. ... 12s. 0d.

Practical Testing of Dynamos and Motors. By Chas. F. Smith, Wh Sc., A.M.I.C.E., A.M.I.E.E. Postage 4d. ... ... 5s. 0d.

Continuous Current Dynamos and Motors and their Control. By W. R. Kelsey, B.Sc., A.I.E.E., F.Ph.S. Postage 4d. ... ... 5s. 0d.

The Management of Dynamos. By G. W. Lummis-Paterson. A Handybook of Theory and Practice for the Use of Mechanics, Engineers, Students, and others in charge of Dynamos. Third Edition, revised. Crown 8vo. Cloth. Postage 3d. .. .. 4s. 6d.

The A.B.C. of Dynamo Design. By Alfred H. Avery, A.I.E.E. With 61 Illustrations and 108 pages. Third Edition. Postage 3d. ... 2s. 0d.

The Application of Electric Motors to Machine Driving. By Andrew Stewart, A.I.E.E. Postage 2d. ... ... 2s. 0d.

Dynamo Attendants and their Dynamos. By F. Broadbent, M.I.E.E. A Practical Book for Practical Men. Fourth Edition. Postage 3d. 1s. 6d.

Practical Dynamo and Motor Construction. By A. W. Marshall, A.M.I.E.E. A Handbook of Constructive Details and Workshop Methods used in building small machines. Postage 3d. ... ... 1s. 0d.

How to Manage a Dynamo. By S. R. Bottone. A Handbook for Engineers, Electric Light Engineers, and Electro Platers. Illustrated. Third Edition, revised and enlarged. Post 8vo. Cloth. Pocket size. Postage 1d. 1s. 0d.

Care and Management of Electrical Machinery. A handbook for the use of power users and attendants. Illustrated. Postage 3d. ... 1s. 0d.

Small Dynamos and Motors: How to Make, Test, and Repair Them. By F. E. Powell. Contains Instructions and Drawings for Making Small Dynamos and Motors of various sizes, from 10 to 500 watts, including tables of suitable windings. Fully Illustrated. Third Edition. Postage 1d. 6d.

Small Electric Motors: How to Make and Use Them. By F. E. Powell, Fully Illustrated with Original Diagrams and Drawings. Postage 1d. 6d.

Electrical Apparatus Simply Explained. Fully Illustrated. Postage 1d. 6d.

Electric Lighting.

Electrical Engineering for Electric Light Artisans and Students. By Slingo and Brooker. Well Illustrated. Postage 6d. ... 12s. 0d.

Electric Ship Lighting. By J. W. Urquhart. A Handbook on the Practical Fitting and Running of Ship's Electrical Plant, for the use of Shipowners and Builders, Marine Electricians, and Seagoing Engineers-in-Charge. Second Edition, revised and extended. With numerous Illustrations. Crown 8vo. Cloth. Postage 4d. ... ... 7s. 6d.

Electric Wiring, Fittings, Switches, and Lamps. By W. Perren Maycock, M.I.E.E. A Practical Book for Electric Light Engineers, Wiring and Fitting Contractors, Consulting Engineers, Architects, Builders, Wiremen, and Students. Third Edition, revised. With 360 Illustrations. Postage 4d. 6s. 0d.

Electric Lighting and Power Distribution. By W. Perren Maycock, M.I.E.E. An Elementary Manual for Students. Fifth Edition, revised.
Vol. I. With 231 Illustrations. Postage 4d. ... ... 6s. 0d.
Vol. II. With 400 Illustrations. Postage 4d. ... ... 7s. 6d.

Practical Electric Light Fitting. By F. C. Allsop. A Treatise on the Wiring and Fitting-up of Buildings deriving current from Central Station Mains, and the Laying-down of Private Installations. With 224 Illustrations. Fourth Edition, revised. Postage 3d. ... ... 5s. 0d.

Electric Wiring. By W. C. Clinton, B.Sc. (Lond.) A Primer for the use of Wiremen and Students. With 80 Illustrations and a selection of Work Examples. Fcp. 8vo. Postage 3d. ... ... 2s. 0d.

Amateur Electrician's Workshop. By S. R. Bottone. A Handbook of Practical Instruction in the Making of Electrical Models and Appliances. In Two Volumes. Postage 2d. each. ... ... Each 1s. 6d.

Private House Electric Lighting. By F. H. Taylor, A.M.I.E.E. Describes Modern Methods in Wiring and Fitting, including a chapter on Small Generating Plants. Postage 3d. ... ... 1s. 0d.

A Guide to Electric Lighting. By S. R. Bottone. For Householders and Amateurs. Pictorial covers Postage 3d. ... ... 1s. 0d.

Electric Lighting for Amateurs. Contains Instructions for fitting up small Electric Installations. Fully Illustrated. Postage 1d. ... 6d.

Electrical Apparatus.

Primary Batteries. Their Theory, Construction, and Use. By W. R. Cooper. Postage 5d. ... ... 10s. 6d.

The Electric Magnet. By Charles R. Underhill, Illustrated. Postage 4d. 6s. 6d.

The Construction of Large Induction Coils. By A. T. Hare. A Workshop Handbook. With 35 Illustrations. 152 pages. Postage 4d. ... 6s. 0d.

Electrical Influence Machines: Their Development and Modern Forms, with Instructions for Making Them. By J. Gray, B.Sc. Second Edition. Revised, with 105 Illustrations. Postage 3d. ... 5s. 0d.

The Induction Coil in Practical Work, including Rontgen X-Rays. By Lewis Wright. With Illustrations. Crown 8vo. Postage 3d. 4s. 6d.

Secondary Batteries. A practical Handbook for Owners and Attendants. By an Engineer. Postage 4d. ... ... 4s. 0d.

Electric Instrument-Making for Amateurs. By S. R. Bottone. A Practical Handbook. With 96 Illustrations. Seventh Edition. Revised and Enlarged. Postage 3d. ... ... 3s. 6d.

Induction Coils. By G. E. Bonney. A Practical Manual for Amateur Coil-makers. Revised. With 101 Illustrations. Postage 3d. 3s. 0d.

Electro Chemistry. By G. Gore. Postage 3d. ... ... 2s. 0d.

Dry Batteries. How to Make and Use Them. By a Dry Battery Expert. Limp Cloth. Postage 1½d. ... ... 1s. 6d.

Experimenting with Induction Coils. By H. S. Norrie. Containing practical directions for operating Induction Coils and Tesla Coils. Limp Cloth. Postage 1½d. ... ... 1s. 6d.

Practical Induction Coil Construction. By John Pike. A handbook of constructive details and workshop methods used in building and repairing modern spark coils. Illustrated. Postage 3d. ... ... 1s. 0d.

Induction Coils for Amateurs: How to Make and Use Them. Edited by Percival Marshall, A.I.Mech.E. Fully Illustrated. Postage 1d. 6d.

Simple Electrical Working Models: How to Make and Use Them. Edited by Percival Marshall, A.I.Mech.E. 43 Illustrations. Postage 1d. 6d.

Small Accumulators: How Made and Used. Edited by Percival Marshall, A.I.M.E. With 41 Illustrations. Seventh Edition. Postage 1d. 6d.

Electric Batteries: How to Make and Use Them. Edited by Percival Marshall, A.I.Mech.E. Fully Illustrated. Sixth Edition. Postage 1d. 6d.

Small Electrical Measuring Instruments. Describes the Making and Using Galvanometers, Voltmeters, &c. Fully Illustrated. Postage 1d. 6d.

The Wimshurst Machines and other Static Electrical Apparatus Simply Explained. By A. W. Marshall. Postage 1d. ... 6d.

Elementary Text Books on Electricity and Magnetism.

The Elements of Electrical Engineering. By Tyson Sewell, A.I.E.E. A First Year's Course for Students. Fourth Edition. Postage 4d. 5s. 0d.

Elementary Lessons in Electricity and Magnetism. By Sylvanus P. Thompson, D.Sc., F.R.S. Illustrated. Fcp. 8vo. Postage 3d. 4s. 6d.

Elementary Manual of Magnetism and Electricity. By Prof. Jamieson. For First Year Students. Fifth Edition. With Illustrations and Examination Papers. Crown 8vo. Postage 3d. ... ... 3s. 6d.

First Book of Electricity and Magnetism. By Perren Maycock, M.I.E.E. Second Edition, revised and enlarged. With 107 Illustrations. Postage 8d. ... ... 2s. 6d.

Magnetism and Electricity for Beginners. By H. E. Hadley, B.Sc. (Lond.) Adapted to the Elementary Stage of the S. Kensington Syllabus. Globe 8vo. Postage 3d. ... ... 2s. 6d.

Problems and Solutions in Elementary Electricity and Magnetism. By W. Slingo and A. Brooker. With 98 Illustrations. Crown 8vo. Postage 3d. ... ... 2s. 0d.

Electrical Engineering. By S. R. Bottone. Gives constructional Details of Appliances described. Illustrated. Postage 3d. ... ...3 2s. 0d.

The Study of Electricity for Beginners. By Norman H. Schneider. Comprising Elements of Electricity and Magnetism. Postage 1½d. 1s. 6d.

Electrical Circuits and Diagrams. By Norman H. Schneider. Gives 217 Diagrams of Connections. Limp Cloth. Postage 1½d.... ... 1s. 6d.

Do. Do. Do. Part II. Alternating Current Generators and Motors, Single phase and Polyphase Transformers, etc., etc. 69 Diagrams. Postage 1½d. ... ... 1s. 6d.

Miscellaneous Electrical Subjects.

Medical Electricity A practical Handbook for Students and Practitioners. 12 plates and Illustrations. Postage 6d. ... ... 12s. 6d.

Electric Traction. By J. H. Rider, M.I.E.E., M.I.C.E. With numerous Illustrations. A Practical Handbook on the Application of Electricity as a Locomotive Power. Crown 8vo. Cloth. Postage 6d. ... 10s. 6d.

The Alternating-Current Circuit and Motor. By W. Perren Maycock, M.I.E.E. An Introductory and Non-Mathematical Book for Engineers and Students. Second Edition. Revised. With 140 Illustrations. Postage 3d. 4s. 6d.

The Electro-Platers' Handbook. By G. E. Bonney. A Practical Manual for Amateurs and Students in Electro Metallurgy. Fourth Edition. Revised and Enlarged, with an Appendix on Nickel Plating for Cycles. Postage 3d. ... ... 3s. 0d.

Electrical Experiments. By G. E. Bonney. A Manual of Instructive Amusement. With 144 Illustrations. Second Edition. Postage 3d.... 2s. 6d.

Simple Experiments in Static Electricity. A Series of Instructive and Entertaining Experiments for Students and Amateurs. Fully Illustrated. Postage 1d. ... ... 6d.

X Rays Simply Explained. A Handbook on the Theory and Practice of Radiography. Fully Illustrated. Postage 1d. ... ... 6d.

Alternating Currents Simply Explained. By A. W. Marshall. Postage 1d. 6d.

Electric Power. What it is and what it can do. By A. W. Marshall, A.M.I.C.E. Postage 1d. ... ... 3d.

Reference and Pocket Books.

A Pocket Book of Electrical Rules and Tables. By J. Munro, C.E., and Prof. Jamieson. With numerous Diagrams. Sixteenth Edition, thoroughly revised and enlarged. For the use of Electricians and Engineers. Leather. Pocket size. Postage 3d. ... ... 8s. 6d.

Molesworth's Pocket Book of Engineering Formulæ. A useful book for Civil, Mechanical and Electrical Engineers. Contains many Tables of interest. Pocket size, 899 pages. Postage 2d. ... ... 5s. 0d.

A Guide to the Electrical Examinations. By F. H. Taylor. A Handbook of Reference for Students and Teachers, with an appendix of specimen Questions and Answers. Cloth. Postage 3d. ... ... 1s. 6d.
Ditto ditto Paper. Postage 2d. ... ... 1s. 0d.

Whittaker's Electrical Engineer's Pocket Book. Edited by Kenelm Edgcumbe, A.M.I.E.E. With 143 Illustrations. Leather. Postage 3d. 3s. 6d.

"The Practical Engineer" Electrical Pocket Book and Diary. (Published annually.) Postage 3d. ... ... 1s. 0d.
Leather, gilt edges, with Pocket and Elastic Band. Postage 2d. 1s. 6d.

Practical Electrician's Pocket-book and Diary. By H. T. Crewe. M.I.M.E. Cloth. Postage 2d. ... ... 1s. 0d.
Leather. Postage 2d. ... ... 1s. 6d.

The Handy Electrical Dictionary. By W. L. Weber, M.E. Gives several thousand definitions. 224 pages. Pocket size. Postage 1d. Cloth. 1s. 0d.
Leather. Postage 1d. ... ... 1s. 9d.

Telephones, Telegraphy, and Bells.

Telegraphy. By Sir W. H. Preece, K.C.B., F.R.S., V.P.In., and Sir J. Sivewright, K.C.M.G. With 267 Illustrations. Fcp. 8vo. Postage 5d. 7s. 6d.

Telegraphy. A Detailed Exposition of the Telegraph System of the British Post Office. By T. E. Herbert, A.M.I E.E. 50 Illustration. 900 pages. Postage 5d. ... ... 6s. 6d.

The Practical Telephone Handbook. By Joseph Poole, A.I.E.E., Wh.Sc. With 473 Illustrations. Third Edition, revised and enlarged. Postage 4d. ... ... 6s. 0d.

Practical Electric Bell Fitting. By F. C. Allsop. Tenth Edition. 186 Illustrations. Crown 8vo. Postage 3d. 3s. 6d

Telephones: Their Construction and Fitting By F. C. Allsop. Eighth Edition. 184 Illustrations. Crown 8vo. Postage 4d.... ... 3s 6d.

Wireless Telegraphy and Hertzian Waves. By S. R. Bottone. Second Edition, revised. With 37 Illustrations. Postage 3d. ... ... 3s. 0d.

Practical Telephony. By Jas. Bell, A.I.E.E., and S. Wilson. A Simple and Practical Handbook for the use of Students and Employees. Copiously Illustrated. Postage 4d. Fourth Edition. Revised 3s. 6d

Electric Bells, and All About Them. By S. R. Bottone. A Practical Book for Practical Men. With more than 100 Illustrations. Seventh Edition, revised and enlarged. Postage 3d. ... ... 2s. 0d.

Telegraphists' Guide. By Jas. Bell, A.I.E.E., and S. Wilson, A M.I.E.E. Sixth Edition. 208 Cuts. Postage 3d. ... ... 2s. 0d.

Wireless Telegraphy for Amateurs. By R. P. Howgrave Graham. Gives full details of construction of apparatus required. 51 Illustrations. Postage 3d. ... ... 2s. 0d.

How to Instal Electric Bells, Annunciators and Alarms. By Norman H. Schneider. Gives some 59 Diagrams. Limp Cloth. Postage 1½d. 1s. 6d.

Making Wireless Outfits. By Newlow Harrison. Illustrated. Post. 1½d. 1s. 6d.

Telephone Troubles and How to Find Them. By W. H. Hyde. A complete Handbook for the Telephone Inspector. Postage 1d. ... 6d.

Electric Bells and Alarms. By F. E. Powell. Gives instructions for fitting same to any part of any ordinary building. 51 Illustrations. Seventh edition. Postage 1d.... ... ... 6d.

Telephones and Microphones: How to Make and Use Them. Edited by Percival Marshall, A.I.Mech.E. A Practical Handbook on the Making and Using of Simple Forms of Telephones and Microphones. Fifth Edition. With 29 Illustrations. Postage 1d.... ... ... 6d.

PERIODICALS

(Continued).

"**The Model Engineer.**" Contains Practical Articles, Original Working Drawings and High-class Illustrations on Model Engine Making, Lathe Work, Pattern Making, Sheet Metal Working, Brass and Iron Founding, Forging, Tool Making, Motor Cycles, Model Yacht Building, Small Dynamos and Motors, Electric Bells, Batteries, Accumulators, Telephones, Influence Machines, Electric Lighting, Electrical Experiments. Every Thursday, 2d. net. Annual Subscription, post free ... ... **13s. 0d.**

Vols. I, II, and III, are entirely out of print.

Vol. IV, Jan. to June, 1901; Vol. V, July to Dec., 1901; Vol. VI, Jan. to June, 1902; Vol. VII, July to Dec., 1902. Postage 4d.; Foreign and Colonial 6d. Each ... ... **3s. 6d.**

Each Vol. contains 12 parts.

Vol. VIII, Jan. to June, 1903; Vol. IX, July to Dec., 1903; Vol. X, Jan. to June, 1904; Vol. XI, July to Dec., 1904; Vol. XII, Jan to June, 1905; Vol. XIII, July to Dec., 1905: Vol. XIV, Jan. to June, 1906; Vol XV, July to Dec., 1906; Vol. XVI, Jan. to June, 1907; Vol. XVII, July to Dec., 1907; Vol. XVIII, Jan. to June, 1908. Vol. XIX, July to Dec., 1908. Postage 6d.; Foreign and Colonial, 1s. Each ... ... **6s. 6d.**

Each Vol. contains 26 parts.

Binding Cases for Vol. Postage 3d. ... **1s. 0d.**

Reading Cases, with Strings for the Temporary Binding of Twelve Parts. Postage 3d. ... **1s. 0d.**

"**The Engineer-in-Charge and Works Manager.**" A Practical Journal of Engineering, Plant Management, and Maintenance. Specially Suitable for Works Managers and Engineers in Public Institutions, Warehouses, Factories, Mills, Power Stations, etc. Thoroughly Practical and fully Illustrated. Monthly 2d. net. Post free 3½d. Annual Subscription, post free **3s. 6d.**

Vol. I. April, 1906, to March, 1907; Vol. II. April, 1907, to March, 1908.; Vol. III, April, 1908 to March, 1909. Postage 5d. Foreign and Colonial 9d. **4s. 6d.**

Binding Cases for Vol. Postage 3d. ... **1s. 6d.**

Reading Cases, with Strings, to hold twelve parts. Postage 3d. ... ... **1s. 6d.**

The A.B.C. of Dynamo Design.

By ALFRED H. AVERY, A.I.E.E.

An Illustrated Handbook describing General Principles of Dynamo Design. Folding Plate of 500-watt Dynamo. Chapters—I. General Principles of Dynamo Design. II. The Armature. III. Armature Action and Reaction. IV. The Construction and Winding of Armatures. V. The Field-Magnet. VI. Design for a 30-watt Dynamo. VII. Design for a 500-watt Dynamo. VIII. Design for a 2-kilowatt Dynamo. IX. Notes on Dynamo Construction and Winding. Price 2s. net; post free, 2s. 3d.

Private House Electric Lighting.

By FREDERIC H. TAYLOR, A.M.I.E.E.

Describes modern methods in Wiring and Fitting, and is fully illustrated. Chapters—I. Systems of Supply. II. Systems of Wiring. III. Arrangements of Circuits and Conductors, etc. IV. Arrangements of Lights and Switches. V. The Testing of an Installation. VI. The Materials and Accessories Used. VII. Cost of Installation Work. VIII. Cost of Using Electric Light. IX. Generating Plant. Price 1s. net; post free, 1s. 3d.

A Guide to the Electrical Examinations.

A Handbook of Reference for Students and Teachers, with an appendix of Specimen Questions and Answers. By FREDERIC H. TAYLOR, A.M.I.E.E., Mem. Society of Arts. Contents—Section I. City and Guilds Department of Technology—Particulars of Examinations in Electric Lighting and Power Transmission—Telegraphy and Telephony and Electro-Metallurgy. II. The Board of Education Examinations in Magnetism and Electricity. III. Particulars of Examination Fees and Certificates and Awards. IV. Notes on the Preparation for Examination. V. Hints on Working Examination Papers. VI. Specimen Questions and Answers. Price, paper cover, 1s. net; post free, 1s. 2d.; cloth, 1s. 6d. net; post free, 1s. 9d.

To be obtained from all Booksellers, or post free from

PERCIVAL MARSHALL & CO.,

26-29, Poppin's Court, Fleet St., London, E.C.